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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

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TOXICITY OF THE LEAVES OF *MACROZAMIA* SPP. FOR CATTLE

By W. T. K. HALL, B.V.Sc., formerly Senior Veterinary Pathologist, Animal Research Institute, Yeerongpilly; now Officer in Charge, Animal Health Station, Oonoonba, North Queensland.

SUMMARY.

An account of feeding tests with three groups of cattle is given. One group was fed the leaves of Macrozamia pauli guilielmi, **a second group mixture of leaves of** M. douglasii **and** M. spiralis, **and a third group the leaves of** M. spiralis.

Two distinct syndromes were produced. One was liver damage seen in animals in the group fed M. pauli guilielmi, **and then only when fresh green leaves were used. The other was an ataxia seen in animals in all three groups. This ataxia affected only the hindquarters and was characterised by a swaying to both left and right and a dropping of the rump. This was associated, in particular, with poorly controlled movements of the tibio-tarsal and metatarso-phalangeal articulations. No lesions to account for this disability were found.**

The toxicity of the leaves is evidently rapidly lowered by drying and withering on exposure to air.

I. INTRODUCTION.

The following statement on the genus *Macrozamia* has been prepared by Dr. S. T. Blake, Botanist, Queensland Department of Agriculture and Stock.

"*Macrozamia* is a genus of the Cycadaceae that is confined to Australia. About a dozen species are known, of which nine are recognised as occurring in Queensland. All species produce a crown of leaves on a stem, each leaf being composed of very many (25-100) narrow, pointed, tough leaflets on each side of a midrib, each leaflet having several fine longitudinal veins without a distinct midrib. The stem may be bulb-like and subterranean or develop into a tall, stout, usually unbranched trunk.

Macrozamia hopei grows to a height of 60 ft. in the scrubs of north-eastern Queensland. *M. denisonii* is a shorter species (up to about 20 ft.) and occurs in the scrubs of south-eastern Queensland. *M. moorei* is about as high as *M. denisonii* but stouter; it is found in drier country than the other Queensland species, chiefly in the southern part of the Leichhardt District, extending over the Great Dividing Range on to the headwaters of the Maranoa. *M. douglasii*, known only from Fraser Island, sometimes forms a short trunk whereas the other species usually have no stem visible above ground. *M. mountperriensis* is known from the country west of Maryborough through Mt. Perry to Eidsvold. *M. miquelii* has been reported from near Brisbane to near Mackay; it is the common species about Rockhampton. *M. spiralis* is the common species about Brisbane

and other parts of the Moreton District. *M. pauli guilielmi* is found here and there in "wallum" country as far north as Rockhampton, occurs in the Stanthorpe district and has been reported from the Maranoa. Very little is known about *M. platyrhachis;* it is recorded only from some range near Planet Downs.

In all species the 'flowers' are arranged in more or less woody cones varying from 3-5 in. long in the case of *M. pauli guilielmi* up to 3 ft. in the case of *M. moorei.* Each plant bears flowers of one sex only, the female cones being thicker and mostly longer than the males. The seeds are large and usually orange or scarlet when ripe; they are shed by the breaking up of the cones into its component scales. The species are distinguished by the presence or absence of spines on the leaf-stalk, the length and breath of the leaflets and the way they are attached to the midrib, the size and shape of the cones, and the shape of the woody scales that compose them."

Investigations and feeding experiments were carried out many years ago by various observers to determine the relationship of these plants to a disease of cattle, the most significant clinical feature of which appeared to be a disturbance of locomotion known as "wobbles" or "rickets." It is still frequently referred to as "rickets."

In "The Queenslander" newspaper of October 29, 1892, there appeared a statement by Dr. T. L. Bancroft, who was commissioned by the Queensland Government to investigate the "rickets" problem. He said that the eating of the zamia palm (*Macrozamia miquelii* and *M. spiralis*) had been thought by many stock-owners to be responsible and stated:

"If it can be shown that the Zamia is the cause, it would be much better to call the disease 'zamia poisoning', for the name 'rickets' has already been used to designate a vary different affection, in which softening of the bones is the main morbid change.

The chief symptom of the disease is loss of proper control over the movements of the hind limbs. A 'rickety' animal may run several yards without showing any peculiarity whatever, when suddenly it may drag its hind limbs much like a dog sick from tick-bite, or knuckle over upon its hind fetlocks, or may fall upon its haunches, immediately afterwards righting itself. . . . Affected animals seem never to recover completely, the weakness of hind-quarters continuing throughout life; but although their infirmity handicaps them in obtaining food, they are capable of being fattened if placed on good feed, and the flesh of those in good condition appears to be quite sound."

Turner (1893) recorded that the disease had been noticed in the district north of the Fitzroy River for at least 20 years. He cited an experiment done by Mr. William Norton, a grazier of Yeppoon, who fed a heifer in a small paddock with scorched zamia plants and fruits. Typical symptoms appeared on the fourteenth day.

Edwards (1894) reported feeding experiments with *M. fraseri* in Western Australia. He reproduced a syndrome similar to that seen naturally. His photographs and description leave no doubt that the condition was very similar to that seen in Queensland.

Lauterer (1898) fed leaves of *M. spiralis* to three calves. Two were given 8 lb. a day for three days and the other 6 lb. a day for six days. The gait was not affected. All three died with severe gastro-enteritis. He concluded that the plant was toxic, but was sceptical about Edwards' conclusions.

Stewart (1899) reported a similar disease in cattle on several properties in the Moruya district of New South Wales. These cattle had leaf fragments of *M. spiralis* in the rumen. His photographs show that the disease was very similar to zamia poisoning in Queensland.

Hunt (1899) said: "'Rickets' in cattle is unquestionably caused by their eating zamia leaves . . . Cattle experimentally fed upon the macrozamia—whether upon the leaves, leaf-stems, bulbs, or young male or female fruit—become affected. The first signs of the paralytic condition generally appear after about fourteen days' zamia-feeding—when 2 to 4 lb. of any part of the plant are consumed per day . . . Cattle removed from contact with zamia after having been even slightly affected with 'rickets' show little or no tendency to spontaneous recovery, neither is their malady progressive." It was stated that the *M. miquelii* and a Cycas palm were the two species experimented with.

Seddon, Belschner and King (1931) reported a severe mortality in sheep which had eaten nuts from *M. spiralis*. There were 2,200 deaths in 6,000 sheep. The first animal died on the day after eating the plant and deaths continued for about three weeks. They confirmed the toxicity of the seeds by experimental feeding to sheep and cattle. The symptoms noted by them included injection of the conjunctivae, a rise in temperature and often an increase in the amount of faeces, which later might be reduced in quantity but remained soft. If the animal died within three days no other symptoms were seen, but if it lived longer icterus was common. Then general depression developed with the animal wandering aimlessly around the pen, tripping over any low object or bumping into the fence.

As part of a programme of investigating the plants poisonous to cattle in Queensland, a series of feeding tests with species of *Macrozamia* was done. The objectives were, briefly:—

(1) To note any variations in the symptoms produced by the different species of zamia. This was to assist with the differential diagnosis of the ataxias seen in cattle grazed in the area.

(2) To test the toxicity of as many species as practicable.

II. FEEDING EXPERIMENTS.

In the experiments detailed below the leaves were freshly chopped in a hand chaffcutter and mixed with lucerne chaff.

(1) Macrozamia pauli guilielmi.

(a) Test 1.

Plant.—Young leaves of this species were obtained from the Gympie district in November 1951. There was an interval of 2-7 days between collecting and feeding, the leaves therefore being relatively fresh.

*Subject**.—Heifer, in good condition, about 300 lb. weight and approximately nine months old.

It ate the mixture of lucerne chaff and zamia readily for the first two days, 2 lb. of zamia being consumed over this period. On the third day it was obviously sick and would not willingly eat the small ration allowed. All attempts to feed zamia ceased after the sixth day because the animal's condition had rapidly deteriorated and it refused to eat. By this time it had eaten 3¾ lb. of zamia and 24 lb. of lucerne chaff.

The animal had now wasted considerably and was put out to graze with other cattle. During the next 10 days it became weaker and grazed little. On the 17th day the temperature was 107·4 deg. F., vision was impaired and shade was sought. The next week saw an abatement of the pyrexia, but the appetite did not improve and the general condition deteriorated further. On the morning of the 28th day it was found dead.

Autopsy.—The carcase was wasted, dehydration being evident. The most prominent lesion was in the liver. This was hard and of an irregular yellow colour; microscopically, it was greatly fibrosed and the parenchyma largely destroyed. There was a severe inflammation of the abomasum, with necrotic areas up to an eighth of an inch in diameter in the mucosa, reddening of the intestinal mucosa and acute congestion of the lungs.

Comment.—Death was undoubtedly due to liver damage. The interval of 22 days between the cessation of feeding and death is compatible with a diagnosis of liver insufficiency.

The amount of 3¾ lb. of relatively fresh zamia leaves consumed was sufficient to cause death.

(b) Test 2.

Plant.—As for Test 1, but the interval between collecting and feeding was 11–24 days. The leaves had dried out.

Subject.—Heifer, in good condition, about 350 lb. weight and approximately nine months old.

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* The cattle used in these trials were mainly Shorthorn crosses.

The beast was given daily a mixture of 1 lb. of zamia leaves and 7 lb. of lucerne chaff for 13 days. It ate readily and was normal throughout.

Comment.—The amount of leaves (13 lb.) eaten in this test was considerably greater than that which caused death of the animal in Test 1, and on a dry matter basis was still greater. The fact that the test animal showed no symptoms of poisoning suggests that the toxic principle is lost or deteriorates very rapidly when the leaves dry out and wither.

(c) Test 3.

Plant.—As for Tests 1 and 2, but collected in January 1952. The material was fresh, feeding commencing the day after it was collected.

Subject.—Heifer, in good condition, about 350 lb. weight and approximately nine months old.

The zamia leaves were mixed with a greatly reduced amount of lucerne chaff and this was eaten readily over the first two days. On the third day the heifer was obviously sick, ate less, was dull and showed photophobia. By the end of the first six days 4 lb. of zamia leaves ($3\frac{3}{4}$ lb. in the first three days) and $11\frac{1}{2}$ lb. of lucerne had been eaten.

Over the next 12 days, 4 lb. of lucerne chaff daily was allowed, but no zamia. Over this period the condition improved.

Peeling of the muzzle was noted on the 21st day, when a general decline, accompanied by a wobbling gait of the hindquarters, set in. Over the 27th to 29th days violent contraction of the abdominal muscles was noted. The animal was destroyed on the 29th day in a comatose condition.

Autopsy.—The subcutaneous tissue and visceral fat were oedematous and many petechiae were present. The liver was swollen, yellow, hard to cut and apparently fibrosed. Microscopic examination of sections showed an advanced portal cirrhosis and some centrilobular fibrosis. Liver cells were recognisable as such, but most were vacuolated. The mucosa of the abomasum was very oedematous. Microscopic examination of sections showed that most of the epithelial cells had lost their nuclei and the cell walls were ragged in appearance. The blood serum was stained a deep yellow, apparently with bile pigment.

Comment.—The results resemble those of Test 1. The interval between the cessation of feeding and death was 22 days in Test 1 and 23 days in Test 3. The animal had consumed 4 lb. of fresh zamia leaves.

(d) Test 4.

Plant.—As for Test 3. The leaves had been collected 11 days before feeding began and had withered to some extent.

Subject.—Steer, in poor condition, about 300 lb. weight and approximately 15 months old.

At first the daily mixture, which consisted of 1–1½ lb. of zamia leaves plus 4–8 lb. of lucerne chaff, was not eaten very readily, but later, when the zamia was drier, the appetite improved. It was estimated that over the 22 days of the test 18½ lb. of zamia and 100 lb. of chaff were eaten.

Clinically there was no abnormality.

Comment.—The result of this test, when compared with results obtained in Tests 1 and 3, suggests that the toxicity of the leaves is rapidly lost by exposure to air after removal from the plant. It also confirms the results of Test 2, inasmuch as the animal consumed over 18 lb. of relatively dry leaves without ill effect.

(e) Test 5.

An attempt was made to study more closely the factors involved in the production of the liver damage seen in Tests 1 and 3.

Plant.—Leaves from more mature plants than those used in Tests 1–4 were collected in the Gympie district in 1953 and fed within a few days of collection.

Subjects.—Two steers, in good condition, of similar size, each about 650 lb. weight and approximately 18 months old.

Each animal, during May, received a small amount of lucerne chaff (4 lb.) each day. One of them (462) received nothing else, but the other (566) was given as much zamia as it could be induced to eat. A series of liver biopsies was made and the serum of each animal analysed by paper electrophoresis. These examinations yielded nothing of significance.

No. 566, the animal fed zamia plus lucerne, ate well for the first five or six days, but the ration appeared to be distasteful. Feeding of zamia was stopped on the 10th day, up to which time 9 lb. of zamia had been consumed.

No symptoms of any kind were noted.

(f) Test 6.

Plant.—As in Test 5.

Subject.—Steer No. 462 from Test 5 above.

Feeding commenced in July 1953 and for the first 46 days 1 lb. of zamia leaves per day was eaten, then for 54 days, 2 lb. per day. In addition 12–20 lb. of lucerne chaff per day was given. The total amount of zamia eaten over a period of 100 days was 154 lb., all of which the animal consumed quite readily.

Mild symptoms of ataxia were seen on the 86th day; they were advanced when feeding stopped on the 100th day. There were no symptoms of liver damage, but there was clearly a disturbance in locomotion, due largely to an over-extension or increase in tone of the extensor muscles of the hind limbs.

Autopsy.—The animal was killed for autopsy. Spinal cord and brain sections were stained with haemotoxylin and eosin and additional spinal cord sections by the Marchi technique. No macroscopic or microscopic abnormality was found.

(g) Test 7.

Subjects.—Two heifers, in good condition, approximately two years old and weighing 700 lb.

One ate 100 lb. of zamia leaves in 80 days without adverse effect. The other ate 116 lb. of zamia leaves with lucerne chaff over a period of 120 days, also without ill effects. On the 66th day it calved normally and the calf did well.

Comment.—Although ataxia was noted in animal No. 462 (Test 6), which ate 154 lb. of zamia in 100 days, it was clear that the leaves were not nearly as toxic as those received from the same district at the end of 1951 and early in 1952.

(h) Summary of Results.

The results are summarised as follows:—

Test Number.	Number of Animals.	Amount of Leaves Fed. (lb.)	Age of Leaves when Fed. (Days.)	Remarks.
1	1	3¾	2– 7	Death 28th day. Liver damage
2	1	13	11–24	No symptoms
3	1	4	1– 4	Death 29th day. Liver damage
4	1	18½	11	No symptoms
5	1 (one control)	9	4–11	No symptoms
6	1	154	4–11	Ataxia only
7	2	100 and 125	4–11	No symptoms

(2) Macrozamia douglasii and M. spiralis.

(a) Test 8.

Plant.—Leaves in various stages of growth were received from Fraser Island in April–May, 1952. The two species were about equally represented. There was an interval of 6–14 days between collecting and feeding, and the leaves became partly dried out.

Subject.—Steer, in good condition, about 400 lb. weight and approximately 18 months old.

It readily ate a mixture of 12 lb. of lucerne chaff and 4 oz. of zamia leaves per day for 35 days.

No symptoms were observed from the eating of $8\frac{3}{4}$ lb. of zamia leaves over the test period.

(b) Test 9.

Plant.—As for Test 8.

Subject.—Steer, in fair condition, about 400 lb. weight and approximately 20 months old.

It was given a mixture of 12 lb. of lucerne chaff and up to 12 oz. of zamia leaves per day. The mixture was not readily taken and when zamia feeding was stopped on the 45th day only $22\frac{1}{2}$ lb. of leaves had been consumed, an average of 8 oz. per day.

The animal remained normal until five days after feeding ceased—i.e., the 50th day. Symptoms similar to those seen in mild natural cases were then observed. These included occasional swaying of the hindquarters, plaiting of the hind legs, knuckling of the fetlock and flexing of the hock. This animal was kept under observation for two years. Its gait never returned to normal though the animal appeared to adapt itself to its disability.

(c) Summary of Results.

The following summarises the results obtained with equal parts of *M. douglasii* and *M. spiralis*:—

Test Number.	Number of Animals.	Amount of Leaves Fed. (lb.)	Age of Leaves when Fed. (Days.)	Remarks.
8	1	$8\frac{3}{4}$	6–14	No symptoms
9	1	$22\frac{1}{2}$	6–14	Mild ataxia

(3) Macrozamia spiralis.

Young leaves in various stages of growth were obtained in the months of June and July, 1952, from the Toogoolawah district. These were used for Tests 10, 11 and 12 detailed below.

(a) Test 10.

Plant.—There was an interval of 4–11 days between collecting and feeding.

Subject.—Steer, in good condition, about 400 lb. weight and approximately 20 months old.

It was given up to 8 lb. of lucerne chaff per day and various amounts of zamia leaves. The quantity of zamia eaten, however, never exceeded 10 oz. per day.

At the end of the 34th day, when feeding with zamia ceased, the animal had consumed an estimated 18 lb. of zamia leaves. Its condition remained good.

Symptoms were first seen on the 30th day, when the gait became slightly affected. Three days later ataxia was marked. The animal appeared sensitive over the hindquarters and hind-legs down to the coronets. After exercise it seemed abnormally frightened and excited.

On the 35th day, the day after feeding ceased, the animal had to struggle to get on to its feet. Turning was difficult and there was frequent knuckling of the fetlocks of the hind-legs. When the animal was started up quickly, its rump dropped due to abnormal flexion of the lower joints of the hind legs.

On the 36th day the hocks were swollen. Blood serum tests showed phosphate to be 4·6 mg. and calcium 10·5 mg. per 100 ml. The animal ate well while clinically affected.

Autopsy.—Autopsy was carried out on the 48th day. Macroscopically, there were bruising and haemorrhages around the hocks and some superficial bruising of the hindquarters. Sections of spinal cord, mid-brain and cerebellum stained with haematoxylin and eosin showed no abnormality.

(b) Test 11.

Plant.—As for Test 10, but the leaves were allowed to dry out in the air until the bright-green colour had changed to a dull brown.

Subject.—Steer, in good condition, about 560 lb. weight and approximately 18 months old.

It was given 12–16 lb. of lucerne chaff per day. For the first 14 days it received in addition 8 oz. of zamia leaves and thereafter 10 oz. per day. It was estimated that over a period of 103 days 62½ lb. of zamia leaves was consumed. It ate readily.

No abnormality was seen during or after the feeding of zamia ceased.

This result confirms the view that drying-out of the leaves causes rapid loss of toxicity. The difference in toxicity is even more striking when it is considered that the loss of moisture must have appreciably increased the weight of dry matter eaten.

(c) Test 12.

Plant.—As for Test 10, the leaves having been collected 4–11 days before feeding.

Subject.—Steer, in good condition, about 500 lb. weight and approximately 18 months old.

It consumed 12–20 lb. of lucerne chaff plus 4 oz. of zamia daily for 114 days, the total weight of zamia leaves eaten being 28½ lb. It ate readily, remained normal throughout and put on condition.

Strenuous exercise produced no abnormal effects.

(d) Test 13.

Plant.—As for Tests 10, 11 and 12, the plant being collected 4–18 days before feeding.

Subject.—Steer used in Test 4.

An attempt was made in this test to induce the animal to eat as much fresh zamia as possible in order to reproduce the symptoms of liver damage seen in two previous tests (1 and 3) with *M. pauli guilielmi.* During the first nine days 5 lb. of leaves was consumed. Between the 20th and 27th days another 6½ lb., and between the 69th and 89th day a further 19½ lb., were eaten, making a total of 31 lb. A considerable quantity of lucerne chaff was also eaten.

On the 87th day typical ataxia was noted; the hindquarters swayed from side to side and knuckling of the fetlock was evident. This condition continued until the animal was destroyed on the 110th day.

Autopsy.—Superficial bruising, probably due to the uncontrolled movements, was noted around the hock joints. Microscopic examination of the liver, spinal cord, femoral nerve and sciatic nerve stained by haematoxylin and eosin and the Marchi method showed no abnormality.

(e) Summary of Results.

Test Number.	Number of Animals.	Amount of Leaves Fed. (lb.)	Age of Leaves when Fed. (Days).	Remarks.
10	1	18	4–11	Ataxia
11	1	62½	Dried out	No symptoms
12	1	28½	4–11	No symptoms
13	1	31	4–18	Ataxia

III. DISCUSSION.

One of the most striking features arising from these trials is the great difference in the degree of toxicity of the batches of leaves fed to the experimental animals.

With *M. pauli guilielmi* the first four trials were carried out with leaves collected from the Gympie district in 1951-52, and it was found that up to 4 lb. of fresh leaves (2–7 days old) was highly toxic to two bovines, whereas large quantities of the same batch of leaves, if exposed to air for 2–3 weeks, were practically non-toxic. This suggests that the toxic principle may be volatile or, on the other hand, breaks down readily.

The tests carried out in 1953 with the same species of zamia were with material collected from the same district. Using three animals and relatively fresh plant, mild ataxia was produced only in one animal, but before this symptom appeared the animal had consumed well over 100 lb. of the leaves during a period of nearly three months. This suggests that there may be also a seasonal variation in the toxicity of the species.

Tests with *M. spiralis* produced ataxia in two of the four animals used, and then only after appreciable quantities of the plant had been consumed.

The findings in Test 10, together with field observations, indicate that the damage to the nervous tissues and/or musculature which results in ataxia is permanent, although no microscopic lesions have so far been detected. Hunt (1899) also observed that there was no tendency to spontaneous recovery from the nervous symptoms in this disease.

Field reports frequently refer to damaged horns. Edwards (1894) thought that this was due to necrosis following contraction of the blood capillaries at the base of the horn-core, and Hunt (1899) suggested that it was referable to failure of nutrition of nervous origin. In the experiments reported here the horn was affected, and it is thought that in the field damage to the horn is probably brought about by the animal blundering into trees or stumps.

Lauterer (1898) was evidently able to induce his animals (calves) to eat large quantities of fresh leaves and thereby produce a gastro-enteritis. Attempts by the author to feed relatively large quantities of leaves in admixture with lucerne chaff to older animals were unsuccessful and no gastro-enteritis was observed.

Stewart (1899) and Edwards (1894) both referred to the incessant and involuntary voiding of urine in females. This feature was not seen in either of the two heifers (Tests 1 and 3) which showed symptoms, though poisoning by the swamp grass-tree (*Xanthorrhoea hastile*), which is to be found in some

of the localities where species of zamia grow, does produce in females a constant dribbling of urine as well as an ataxia not unlike that seen in zamia poisoning.

The absence of necrosis, the even distribution of the lesions and the portal fibrosis found in the livers of the experimental animals autopsied in Tests 1 and 3 suggest that the change probably started as a mild degeneration, and that complete destruction and disappearance of many liver cells and their replacement by fibrous tissue followed. Himsworth (1948) pointed out that secondary changes often obscure the primary lesions.

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CONTROL OF *THRIPS TABACI* LIND. IN ONION CROPS IN THE LOCKYER VALLEY

By T. PASSLOW, B.Sc.Agr., Entomologist, Science Branch, Division of Plant Industry.

SUMMARY.

Thrips tabaci **Lind. is normally present in bulb and seed onion crops in the Lockyer Valley, the major commercial onion district in Queensland.**

During 1951-55 an investigation of the pest status of this insect included 11 screening and field trials under irrigated conditions, using 14 insecticides. Thrips populations were reduced satisfactorily by several insecticides, but parallel yield increases were not obtained consistently.

In irrigated plantings, unthrifty onion plants, rather than vigorous ones, carry large thrips populations, and are also more susceptible to thrips damage. Irrigation of onion crops in the Lockyer Valley, as carried out over the past decade, has in effect reduced the status of thrips as a pest, and has forestalled the benefits which might have been derived from the use of modern insecticides under the older dry-farming conditions.

I. INTRODUCTION.

Commercial onion growing in Queensland is confined almost entirely to the south-eastern corner of the State, particularly the Lockyer Valley, and most crops receive some supplementary watering.

Thrips tabaci Lind. is normally present in onion crops, and populations are sometimes sufficiently large to cause plant injury. The thrips feed by rasping the tissues and extracting sap; most feeding occurs on the newly formed leaves. The feeding punctures expand with plant growth and elongate to form small whitish spots and streaks which are the typical symptoms of thrips attack. Following intense pest activity the older leaves present a silvery-white stippled appearance (Fig. 1).

Thrips tabaci as a pest of onions has received attention in many countries.

In general, workers in the United States of America have used heavy insecticide loads. Sleesman (1946), for example, obtained significant increases in bulb yields with four weekly applications of 2 lb. DDT per acre. Peay and Sorensen (1946), using 5 per cent. and 10 per cent. DDT dusts, trebled seed yields after two applications. Wilcox and Howland (1948) and Wilcox, Howland and Campbell (1949) also increased bulb and seed yields with weekly and fortnightly applications of both DDT dusts and sprays.

Harrison and Jacks (1952) and Jacks and Harrison (1953) reported experiments with a number of materials in several combinations against *T. tabaci* in New Zealand, and recommended applications of DDT emulsion at the rate of 1 lb. p.p.i. per 100 gal. made at intervals of 10 days from early

Fig. 1.
Symptoms of Thrips Injury to Maturing Onion Leaves.

November until 14 days before harvest. At this rate of application DDT emulsion gave better control of *T. tabaci* than the other promising materials such as parathion (E605), Isopestox, TEPP, and lindane.

In New South Wales, Hely (1945) found that a 0.1 per cent. DDT emulsion at 96 gal. per acre was more effective in controlling thrips numbers than either a 1.0 per cent. DDT dust at 32 lb. per acre or a tartar emetic bait spray at 48 gal. per acre. DDT emulsion was outstanding and gave economic increases in yields.

From early work in Queensland, Summerville (1933) and Veitch (1938) recommended derris dust in preference to nicotine for reducing thrips numbers on onions, and in the Queensland Agricultural and Pastoral Handbook (officers of the Department of Agriculture and Stock 1951) DDT as a 0.1 per cent. spray is mentioned as a control.

In the Lockyer Valley, winter temperatures usually restrict thrips breeding, so early crops can be harvested during spring before pest injury occurs. The combination of a mild dry winter and a hot dry spring often results in thrips injury to both bulb and seed crops. Although thrips control is not routine procedure in bulb crops, insecticides are sometimes used, with indifferent results. The opinion of growers is that thrips are probably a more important pest in seed crops, but there is a general reluctance to use insecticides after commencement of flowering. The present investigation was undertaken to clarify the problem of thrips as a pest of onions in this district.

II. BULB CROP TRIAL.

Two screening trials were carried out in 1950 and one in 1951. Two field trials were conducted each year in 1951, 1952 and 1955. All trials were irrigated.

In screening trials, thorough plant cover was obtained by using small continuous hand atomisers and hand dusters. In field trials, treatments were applied by knapsack at approximately 100 gal. wet spray and 50 lb. dust per acre. Strengths and dosages are expressed as active ingredients. The details of treatments and relevant comments are given with the results of trials.

Downy mildew (*Peronospora destructor* (Berk) Coop.) was active in the 1952 Gatton trial and during 1955. Infection was light in 1952, and copper oxychloride-detergent was applied three times at fortnightly intervals. In 1955 the Grantham trial received three applications and the Gatton trial two applications of zineb dispersible powder.

(1) Materials.

Aldrin.—An emulsifiable preparation containing 20 per cent. w/v active ingredient.

BHC.—A 50 per cent. dispersible china clay powder containing 6·5 per cent. gamma isomer.

Chlordane.—An emulsifiable concentrate containing 80 per cent. w/v active ingredient.

DDT.—An emulsion concentrate containing 25 per cent. w/v *p.p'* isomer.

A dispersible china clay powder containing 50 per cent. *p.p'* isomer.

A kaolin dust containing 2·0 per cent. *p.p'* isomer.

Derris.—A talc dust containing 0·75 per cent. active ingredients.

Dieldrin.—An emulsifiable preparation containing 16 per cent. w/v active ingredient.

Endrin.—An emulsifiable preparation containing 20 per cent. w/v active ingredient.

Nicotine.—A concentrate containing 40 per cent. nicotine as nicotine sulphate.

Parathion (E605).—An emulsifiable preparation containing 25 per cent. w/v active ingredient.

A dust containing 1·5 per cent. active ingredient.

Pyrethrum.—A proprietary dust containing 0·24 per cent. pyrethrins and 1·2 per cent. technical piperonyl butoxide.

Sodium fluoroacetate (1080).—A concentrate powder containing not less than 90 per cent. sodium fluoroacetate.

Systox.—An emulsifiable preparation containing 50 per cent. w/v active ingredients.

Toxaphene.—An emulsifiable preparation containing 60 per cent. w/v active ingredient.

A kaolin dust containing 2 per cent. active ingredient.

Tartar emetic.—A spray containing 1 oz. tartar emetic and 4 oz. sugar to 4 gal. water.

(2) Designs of Trials.

Randomised blocks were used in all trials. Plot size for screening trials varied from 21 ft. to 35 ft. of row, and for field trials was 1/200 acre.

(3) Assessing Results.

(a) Pest Populations.

Counts of mature thrips visible on the five inner leaves were made in the 1950 trials; these were carried out immediately prior to and 1 day and 7 days after treatments (unless otherwise mentioned) on 10 plants taken at random on

Table 1.

REDUCTION IN PEST NUMBERS.

(1950, Gatton Trial A.)

Treatment.	First Application.					Second Application.				
	Pre-treatment Mean*. Aug. 30.	1 Day After Treatment.		7 Days After Treatment.		Pre-treatment Mean. Sept. 13.	1 Day After Treatment.		7 Days After Treatment.	
		Transformed Mean.	Equiv. % Reduction.	Transformed Mean.	Equiv. % Reduction.		Transformed Mean.	Equiv. % Reduction.	Transformed Mean.	Equiv. % Reduction.
(1) BHC 0·1%	49·0	78·3	95·9	51·8	61·8	51·7	75·0	93·3	54·0	65·4
(2) Toxaphene dust 2·0%	39·7	76·0	94·1	46·5	52·6	51·3	73·3	91·7	47·1	53·7
(3) DDT emulsion 0·1%	46·0	73·3	91·7	59·0	73·5	51·0	73·9	92·3	60·5	75·8
(4) Chlordane dust 2·0%	46·7	73·2	91·7	45·9	51·6	52·3	72·1	90·6	48·9	56·8
(5) Parathion 0·0125% ..	44·0	64·0	80·8	51·0	60·4	52·7	70·2	88·6	41·0	43·1
(6) Nicotine spray 0·064%	40·0	53·8	65·1	−11·4	−3·9	70·0	60·4	78·5	31·8	27·8
(7) DDT dust 2·0% ..	51·3	47·6	54·6	42·1	45·0	80·7	72·9	91·4	46·4	52·4
(8) DDT dispersible powder 0·1%	51·7	34·2	31·6	37·7	37·4	75·7	68·2	86·2	44·0	48·3
(9) Tartar emetic ..	38·7	17·5	9·0	−4·5	−0·6	61·7	61·7	77·5	47·0	53·5
(10) Check	46·0	−11·5	−4·0	·1	0	79·3	36·1	34·7	30·1	25·2
Necessary differences for significance 5%	..	28·6	..	36·5	..	..	7·1	..	17·4	..
Necessary differences for significance 1%	..	39·2	..	50·1	..	..	9·8	..	23·8	..

* Based on counts from 10 plants per plot.

each counting date from the central row in each plot. Analysis of the data from the 10 x 3 screening trial of 1950 indicated that an improvement in method was necessary. In later work, therefore, where detailed information on pest kills was sought the plants necessary to obtain a datum number of thrips, at least 150, were counted in the check plots and a similar number was then examined in each treated plot. A new plant number was determined when the interval between counts exceeded two days.

Except for the small trial at Gatton, using systemic insecticides, results are given as the pre-treatment mean numbers of thrips per plot, the post-treatment transformed means per plot and the equivalent percentage reduction based on the appropriate pre-treatment count. Thrips numbers were transformed by means of the inverse sine transformation: negative values indicate a population increase between counts.

(b) Yields.

At harvesting the number and the weight of trimmed mature bulbs were recorded from a datum area in each plot.

(4) Results of Screening Trials.

(a) 1950, Gatton Trial A, 10 x 3 Randomised Block.

Three applications, commencing on Aug. 30, were made at intervals of two and three weeks, and thrips counts were associated with the first two. The results are given in Table 1. On the basis of these, tartar emetic, nicotine, DDT dust and DDT dispersible powder were discarded.

(b) 1950, Gatton Trial B, 6 x 3 Randomised Block.

Results were assessed as plot population counts nine days after the first application on Sept. 21 and eight days after the second on Oct. 6; they are summarised in Table 2. None of the other insecticides, at the dosages used, compared favourably with 0·1 per cent. DDT emulsion.

Table 2.

THRIPS POPULATIONS.
(1950, Gatton Trial B.)

Treatment.	Pre-treatment Sept. 20.	Post-treatment Sept. 30.	Pre-treatment Oct. 5.	Post-treatment Oct. 14.
(1) DDT emulsion 0·1%	73·3	41·7	34·0	14·3
(2) Parathion spray 0·0125% ..	44·7	66·0	36·7	29·3
(3) Systox spray 0·1%	49·3	79·3	48·0	28·7
(4) Systox spray 0·2%	66·7	89·7	42·3	26·0
(5) Sodium fluoroacetate spray 0·01%	44·0	88·3	49·3	33·3
(6) Check	44·7	97·0	48·7	35·0

Table 3.

REDUCTIONS IN PEST NUMBERS.

(1951, Forest Hill.)

Treatment.	First Application.			Second Application.				
	Pre-treatment Mean*. Aug. 28.	7 Days After Treatment.		Pre-treatment Mean†. Sept. 10.	1 Day After Treatment.		7 Days After Treatment.	
		Transformed Mean.	Equiv. % Reduction.		Transformed Mean.	Equiv. % Reduction.	Transformed Mean.	Equiv. % Reduction.
(1) DDT emulsion 0·1% ..	58·3	28·8	23·2	120·0	87·5	99·8	63·3	79·8
(2) Chlordane spray 0·1% ..	58·7	10·9	3·6	102·7	84·5	99·1	49·6	58·1
(3) BHC 0·05%	53·0	16·2	7·8	110·7	88·2	99·9	53·2	64·1
(4) Toxaphene spray 0·1% ..	64·0	12·1	4·4	115·0	66·1	82·2	37·3	36·8
(5) Aldrin 0·1%	62·0	30·7	26·1	85·7	83·5	98·7	38·2	38·2
(6) Dieldrin 0·1%	56·0	44·2	48·5	66·3	81·0	97·6	55·4	67·8
(7) Derris	57·7	11·3	3·8	117·3	64·1	80·9	40·0	41·3
(8) Chlordane dust 2·0% ..	54·7	−2·6	−0·2	104·7	81·8	98·0	47·3	54·1
(9) Toxaphene dust 2·0% ..	60·7	31·9	27·9	111·7	80·1	97·0	44·6	49·4
(10) Check	53·3	−32·9	−29·5	126·0	6·6	1·3	4·5	0·6
Necessary differences for significance 5%	..	42·0	..	..	14·7	..	20·6	..
Necessary differences for significance 1%	..	57·5	..	..	20·2	..	28·2	..

* Based on counts from 10 plants per plot.

† Based on counts from 15 plants per plot.

Table 4.

REDUCTIONS IN PEST NUMBERS, AND YIELDS.

(1951, Forest Hill Trial A.)

Treatment.	First Application.			Second Application.			Yields.	
	Pre-treatment Mean*. Aug. 27.	7 Days After Treatment.		Pre-treatment Mean†. Sept. 11.	7 Days After Treatment.		Mean Number of Bulbs.	Weight. (lb./Plot.)
		Transformed Mean.	Equiv. % Reduction.		Transformed Mean.	Equiv. % Reduction.		
(1) DDT emulsion 1·25 lb./acre	161	33·1	29·8	166	50·8	60·0	514·0	93·7
(2) DDT emulsion 0·53 lb./acre	156	33·1	29·8	175	54·3	65·9	496·8	93·0
(3) BHC 0·21 lb./acre ..	170	20·6	12·3	172	34·1	31·4	529·0	92·9
(4) Chlordane dust 0·82 lb./acre	156	−2·1	−0·13	168	46·7	53·0	485·0	92·2
(5) Toxaphene dust 0·76 lb./acre	167	−1·3	−0·05	207	39·8	41·0	494·5	88·6
(6) Check	165	−46·1	−51·9	230	−8·7	−2·3	497·0	89·6
Necessary differences for significance 5%	..	38·6	..	..	19·2	..	37·8	4·8
Necessary differences for significance 1%	..	53·4	..	..	26·5	..	52·3	6·6

* Based on counts from 23 plants per plot.

† Based on counts from 15 plants per plot.

(c) 1951, Forest Hill, 10 x 3 Randomised Block.

In this trial the more promising materials of earlier trials and several newer insecticides were used. Two applications were made at an interval of two weeks. Population assessments were made one week after the first application, and 1 day and 7 days after the second. The results are set out in Table 3. The most persistent kills were obtained with dieldrin and DDT.

(5) Results of Field Trials.

(a) 1951, Forest Hill Trial A, 6 x 4 Randomised Block.

Two applications of insecticides were made at an interval of two weeks. Population assessments were made in association with both applications and harvesting was on Oct. 22-24. The results are given in Table 4. The efficacy of DDT was not impaired by reducing the dosage to 0·53 lb. per acre.

(b) 1951, Forest Hill Trial B, 6 x 4 Randomised Block.

Two applications of the insecticides were made at an interval of three weeks. Population assessments were made in association with the first application and a pre-treatment count was taken before the second. Harvesting was on Nov. 1 and 2. The results are given in Table 5. As in the previous trial, best kills were obtained with DDT. The addition of parathion to the weaker DDT strengths did not increase efficacy.

(c) Comments on 1951 Forest Hill Trials.

Both 1951 Forest Hill trials were adequately irrigated in the early stages but were somewhat neglected during the final month. Treated plots, particularly in Trial B, were much less injured than check plots. Differences in leaf stippling were not reflected in yields.

(d) 1952, Grantham, 4 x 6 Randomised Block.

Four applications averaging 100 gal. per acre were made at fortnightly intervals commencing on Sept. 2. Detailed data on pest kills were not taken, only pre-treatment counts being made before the first, second and fourth applications. The mean counts in check plots were 16·6, 23·2 and 18·9 thrips per plant for the first, second and fourth pre-treatments. There were no significant differences among treatments. Harvesting was on Nov. 26 and 27. Yields are given in Table 6.

Table 5.

REDUCTIONS IN PEST NUMBERS, AND YIELDS.

(1951, Forest Hill Trial B.)

Treatment.	First Application.			Second Application.	Yields.	
	Pre-treatment Mean*. Sept. 19.	9 Days After Treatment.		Pre-treatment Mean*. Oct. 11.	Mean Number of Bulbs.	Weight. (lb./Plot.)
		Transformed Mean.	Equiv. % Reduction.			
(1) DDT emulsion 1·17 lb./acre	214·0	57·2	70·7	234·0	502·2	72·4
(2) DDT emulsion 0·54 lb./acre	208·0	49·7	58·1	252·0	505·0	72·2
(3) BHC 0·221 lb./acre	197·5	42·2	45·2	252·5	516·2	74·9
(4) Parathion spray 0·11 lb./acre	181·5	42·0	44·9	245·0	505·0	77·2
(5) Parathion spray 0·06 lb. plus DDT emulsion 0·57 lb./acre	197·0	50·9	60·2	250·0	513·2	73·6
(6) Check	179·0	−12·0	−4·4	301·0	505·2	69·4
Necessary differences for significance 5%	..	16·3	..	..	46·6	6·2
Necessary differences for significance 1%	..	22·6	..	..	64·5	8·6

* Based on counts from 15 plants per plot on each date.

Table 6.

YIELDS.

(1952, Grantham.)

Treatment.	Table Grade.		Pickling Grade.		Total Bulbs.	
	Plot Mean.	Weight. (tons/ac.)	Plot Mean.	Weight. (tons/ac.)	Plot Mean.	Weight. (tons/ac.)
(1) DDT emulsion ½ lb./acre	389·8	13·75	112·0	1·07	501·8	14·80
(2) Parathion spray 1/10 lb./acre ..	404·3	13·82	102·5	1·04	506·8	14·85
(3) Dieldrin ½ lb./acre	409·8	16·58	68·3	·75	478·2	17·33
(4) Check	394·5	13·00	106·3	1·02	500·8	14·02
Necessary differences for significance 5%	55·1	1·42	38·8	·32	88·2	1·45
Necessary differences for significance 1%	76·2	1·96	53·7	·44	122·0	2·01

(e) 1952, Gatton, 4 x 6 Randomised Block.

Four applications, commencing on Sept. 16, were made at fortnightly intervals. Detailed data on pest kills were not taken, only pre-treatment counts being made before the first, third and fourth applications. The mean counts in the check plots were 11·5, 8·9 and 4·7 thrips per plant for the first, third and fourth pre-treatments. There were no significant differences between treatments. Harvesting was on Nov. 29. Yields are given in Table 7.

Table 7.

YIELDS.

(1952, Gatton.)

Treatment.	Table Grade.		Pickling Grade.		Total Bulbs.		
	Plot Mean.	Weight. (tons/ac.)	Plot Mean.	Weight. (tons/ac.)	Plot Mean.	Weight. (tons/ac.).	
						Observed.	Adjusted.
(1) DDT emulsion ½ lb./acre	392·7	13·5	41·3	·50	434·0	14·00	14·29
(2) Parathion spray 1/10 lb./acre	375·7	13·2	39·2	·50	414·8	13·75	14·53
(3) Dieldrin ½ lb./acre ..	413·5	15·3	48·7	·60	462·2	15·95	15·52
(4) Check	418·3	13·5	52·5	·63	470·8	14·12	13·47
Necessary differences for significance 5%	65·2	2·1	13·3	·18	64·7	..	1·36
Necessary differences for significance 1%	90·1	2·9	18·4	·24	89·5	..	1·89 (approx.)

Table 8.

REDUCTIONS IN PEST NUMBERS, AND YIELDS.

(1955, Grantham.)

Treatment.	First Application.							Second Application.	Yields.		
	Pre-treatment Mean*. Oct. 3.	1 Day After Treatment.		7 Days After Treatment.		14 Days After Treatment.		Pre-treatment Mean†. Oct. 20.	Mean Number of Bulbs.	Weight.	
		Transformed Mean.	Equiv. % Reduction.	Transformed Mean.	Equiv. % Reduction.	Transformed Mean.	Equiv. % Reduction.			Observed Mean. (lb./Plot.)	Adjusted Mean. (lb./Plot.)
(1) DDT emulsion ½ lb./acre	176·5	80·3	97·2	65·0	82·1	59·9	74·8	44·5	447·8	56·9	53·0
(2) Dieldrin ½ lb./acre	172·0	89·0	100·0	75·7	93·9	67·7	85·6	25·5	415·8	56·2	56·0
(3) Dieldrin ½ lb./acre + white oil 1 : 100 (wetting agent)	195·0	84·1	98·9	68·9	87·0	68·4	86·4	28·0	401·2	51·5	53·1
(4) Endrin ½ lb./acre	168·5	83·9	98·9	69·5	87·7	63·3	79·8	36·0	400·0	52·2	53·9
(5) Endrin ¼ lb./acre + white oil 1 : 100 (wetting agent)	181·0	81·6	97·9	71·7	90·1	60·6	76·0	45·0	377·0	51·1	55·5
(6) Check	136·5	(29·5)	24·3	35·0	32·9	55·4	67·7	44·0	445·0	51·6	48·0
Necessary differences for significance 5%	..	7·3	..	19·9	..	11·4	..	..	69·0	10·9	7·4
Necessary differences for significance 1%	..	10·2	..	27·5	..	15·8	..	..	95·4	15·0	(approx.) 10·3

* Based on counts from 10 plants per plot.

† Based on counts from 20 plants per plot.

Yield increases followed the application of dieldrin in both 1952 trials.

Irrigation and cultural routine were controlled in both trials, and there were no growth checks. The beneficial effects of dieldrin were apparent from shortly after the first treatments in both trials: the plants were a better colour but stippling was not severe in the check plots. The yield increases therefore were not due to thrips kills. This fact was supported by the lack of significant differences amongst treatments in the pre-treatment numbers of thrips.

(f) 1955, Grantham, 6 x 4 Randomised Block.

Two applications, commencing on Oct. 4, were made at an interval of two weeks. Population assessments were made in association with the first application. Harvesting was from Nov. 28 to Dec. 1. The results are given in Table 8.

(g) 1955, Gatton, 6 x 4 Randomised Block.

Three applications, commencing on Oct. 5, were made at intervals of two and three weeks. Population assessments were made in association with the first application. Harvesting was on Dec. 6. The results are given in Table 9.

The 1955 trials received adequate irrigation, and there were no growth checks.

Pest kills by the lower dosages of dieldrin and endrin, with the addition of white oil, were as good as those by the higher dosages of these materials.

(5) Discussion.

Most insecticides tested in field trials considerably reduced thrips populations. Dieldrin, endrin, DDT, parathion, BHC, chlordane and toxaphene were all efficacious, in that order.

Significant yield increases were obtained in the 1952 trials following four applications of dieldrin spray at ½ lb. per acre. The check pre-treatment counts were 16·6, 23·2 and 18·9 thrips per plant for the first, second and fourth applications in the Grantham trial. In the Gatton trial these counts were 11·5, 8·9 and 4·7 for the first, third and fourth applications. There were no significant differences between these figures and counts in treated plots.

In the 1951 Forest Hill trials, where two applications were applied, the pre-treatment check populations were 7·2 and 15·3 thrips per plant in Trial A and 11·9 and 20·1 in Trial B. In the 1955 Grantham trial, where two applications were made, pre-treatment populations were 13·7 and 2·2 thrips

Table 9.

REDUCTION IN PEST NUMBERS, AND YIELDS.

(1955, Gatton.)

Treatment.	First Application.				Second Application.	Yields.		
	Pre-treatment Mean*. Oct. 3.	1 Day After Treatment.	7 Days After Treatment.		Pre-treatment Mean†.	Mean Number of Bulbs.	Weight.	
		Mean Number of Thrips*.	Transformed Mean.	Equiv. % Reduction.			Observed Mean. (lb./Plot.)	Adjusted Mean. (lb./Plot.)
(1) DDT emulsion ½ lb./acre ..	134	3·5	54·4	66·0	135·0	398·5	51·8	51·4
(2) Dieldrin ½ lb./acre	154	0·25	63·4	80·0	90·0	422·5	55·8	53·3
(3) Dieldrin ¼ lb./acre + white oil 1 : 100 (wetting agent) ..	156	2·0	65·1	82·2	83·0	380·8	49·5	50·7
(4) Endrin ½ lb./acre	162	0·5	62·6	78·9	80·0	429·5	57·2	54·2
(5) Endrin ¼ lb./acre + white oil 1 : 100 (wetting agent) ..	125	1·25	57·2	70·6	85·5	380·5	48·0	49·2
(6) Check	166	(155·5)	17·2	8·7	134·0	353·2	43·2	46·7
Necessary differences for significance 5%	..	..	22·2	..	..	125·7	13·2	7·8 (approx.)
Necessary differences for significance 1%	..	..	30·7	..	..	173·9	18·3	10·8

* Based on counts from 15 plants per plot on each date.

† Based on counts from 20 plants per plot.

per plant. In the Gatton trial in the same year three applications were made and pre-treatment populations for the first two were 11·1 and 6·7 thrips per plant. In all these trials, except for dieldrin in the 1955 Grantham trial there were no significant differences amongst pre-treatment counts for treatments and checks. The population levels, where no yield increases resulted, ranged from 2·2 to 20·1 thrips per plant; with yield increases the range was 4·7 to 23·2. The yield increases therefore, as mentioned earlier (page 65), were not related to thrips control. To clarify the position further, a series of trials would be necessary, using weekly and fortnightly insecticide applications and correlating the results from these treatments with a wide range of thrips populations.

The economic status of the problem at present, and the results which could be expected, do not warrant the large amount of work involved.

III. SEED CROP TRIALS.

A screening trial was conducted in 1951 and a field trial in 1952. Both trials were irrigated.

In both trials, thorough plant cover was obtained using small continuous hand atomisers and hand dusters. All insecticide applications were made in the pre-flowering period in the screening trial. In the field trial, six applications were within this period and all treatments except one DDT treatment were continued for three applications during the flowering stage. The details of treatments and relevant comments are given with the results of the trials.

Downy mildew (*Peronospora destructor*) was severe in the field trial, and for entomological trial purposes six applications of copper oxychloride-detergent were not efficacious.

(1) Materials.

The materials used are included in the list on pages 55–56.

(2) Design of Trials.

Randomised blocks were used in both trials. Plot size in the screening trial was five sets and in the field trial 10 sets.

(3) Assessing Results.

(a) Pest Populations.

Counts of mature thrips visible on the five inner leaves were made on the number of shoots necessary to give a datum number of thrips, at least 150, in the check plots. A similar number was examined in the treated plots. A new shoot number was determined when the interval between counts exceeded two days.

Table 10.

REDUCTION IN PEST NUMBERS.

(1951, Forest Hill.)

Treatment.	First Application.							Second Application.		
	Pre-treatment Mean*. July 12.	7 Days After Treatment.		14 Days After Treatment.		21 Days After Treatment.		Pre-treatment Mean†. Aug. 2.	7 Days After Treatment.	
		Transformed Mean.	Equiv. % Reduction.	Transformed Mean.	Equiv. % Reduction.	Transformed Mean.	Equiv. % Reduction.		Transformed Mean.	Equiv. % Reduction.
(1) DDT emulsion 0·1%	146·3	79·8	96·9	59·6	74·4	51·5	61·2	77·7	83·4	98·7
(2) DDT dust 2·0% ..	188·0	65·9	83·3	47·1	53·7	47·9	55·0	117·0	80·8	97·4
(3) BHC 0·1%	178·9	74·0	92·4	47·7	54·8	47·5	54·3	108·3	78·1	95·8
(4) Chlordane dust 2·0%	162·0	73·6	92·0	45·3	50·5	55·6	68·1	69·0	68·5	86·6
(5) Toxaphene dust 2·0%	164·3	65·2	82·4	38·9	39·4	49·1	57·1	93·7	71·6	90·1
(6) Parathion dust 1·5%	184·7	77·3	95·1	48·3	55·8	58·5	72·8	67·0	72·2	90·7
(7) Aldrin 0·1%	172·0	78·4	96·0	60·2	75·3	58·6	72·8	64·3	73·7	92·1
(8) Dieldrin 0·1% ..	161·3	58·6	72·8	39·7	40·9	55·0	67·0	71·0	79·5	96·7
(9) Toxaphene spray 0·1%	181·7	62·5	78·7	40·8	42·7	54·4	66·1	82·0	76·9	94·9
(10) Chlordane spray 0·1%	192·7	65·4	82·7	39·9	41·2	50·0	58·7	105·3	78·5	96·0
(11) Pyrethrum	204·7	44·3	48·8	36·4	35·2	44·8	49·6	136·3	50·0	58·7
(12) Systox 0·05% at 1 gal. per sq. yd.	166·3	74·9	93·2	54·4	66·2	61·4	77·0	51·0	76·6	94·6
(13) Check	153·0	4·8	0·7	3·2	0·3	39·7	40·9	126·3	34·8	32·6
Necessary differences for significance 5%	..	15·9	..	18·2	..	10·1	..	..	14·7	..
Necessary differences for significance 1%	..	21·6	..	24·6	..	13·7	..	..	19·9	..

* Based on counts from 21 shoots per plot.

† Based on counts from 28 shoots per plot.

Results are given as the pre-treatment mean number of thrips per plot, the post-treatment transformed means per plot, and the equivalent percentage reductions in the screening trial. Thrips numbers were transformed by means of the inverse sine transformation: negative values indicate a population increase between counts. In the field trial only pre-treatment population assessments were made and these are expressed as thrips per plant.

(b) Yields.

All seedheads in the field trial were collected at maturity and divided into seed-bearing, sterile "white heads" and those sterile as a result of mildew. After thorough drying, the seed-bearing heads were threshed and winnowed. Results were assessed on weight of clean seed and number of seed-bearing heads. Germination tests were made by the Standards Branch of this Department.

(4) Results of Screening Trial.

(a) 1951, Forest Hill, 13 x 3 Randomised Block.

Three applications, commencing on July 12, were made at intervals of three and four weeks. Population assessments were made in association with the first two applications. The results are given in Table 10. On the basis of these results and those from earlier work on bulb crops, DDT, aldrin, dieldrin and parathion were used in the field trial.

(5) Results of Field Trial.

(a) 1952, Gatton, 6 x 4 Randomised Block.

Nine applications of all treatments except one DDT treatment were made at intervals of a fortnight commencing on July 1. Pre-treatment assessments of populations were made prior to the first five applications. Harvesting was from Dec. 8 to Dec. 17. The results are given in Table 11.

There were no significant differences in germination amongst treatments.

(6) Discussion.

All insecticides applied in the screening trial reduced *T. tabaci* population levels, with systox having the most prolonged efficacy.

In the field trial, populations varied from 3·8 to 13·8 mature thrips per plant in check plots. With the appreciable complication of losses from downy mildew, yield differences due to thrips attack were not obtained. Fortnightly spray applications did not affect pollination, and germination was not impaired by sprays applied during flowering.

Table 11.

THRIPS NUMBERS, AND YIELDS.

(1952, Gatton.)

Treatment.	Pre-treatment Counts.					Yields.			
	Mean Number of Thrips Per Plant*.					Number of Heads.			Weight of Seed. (g./Plot.)
	First.	Second.	Third.	Fourth.	Fifth.	Sterile (Mildew Damage).	Sterile ("White Heads.").	Seed-bearing.	
(1) DDT emulsion 0·1%, preflowering sprays only	12·5	11·5	8·1	2·2	8·9	24·0	4·5	45·0	69·8
(2) DDT emulsion 0·1%, preflowering and flowering sprays	10·2	6·2	7·8	2·5	9·5	17·8	7·5	49·0	71·4
(3) Parathion spray 0·125% applied as (2)	10·8	6·5	7·8	2·5	5·3	22·0	10·3	38·0	66·9
(4) Dieldrin 0·1% applied as (2) ..	13·1	2·2	5·2	0·9	1·8	27·0	7·3	37·5	62·9
(5) Aldrin 0·1% applied as (2) ..	9·1	6·8	4·1	2·3	2·8	25·3	7·0	55·3	99·4
(6) Check	10·4	13·8	11·5	3·8	11·9	28·0	1·7	33·5	53·6
Necessary differences for significance 5%	..	..	..	..	..	..	..	18·2	31·2
Necessary differences for significance 1%	..	..	..	..	..	..	..	25·2	43·2

* Based on counts from 20 plants per plot.

IV. GENERAL DISCUSSION AND CONCLUSIONS.

Field observations in irrigated plantings invariably indicate that unthrifty onion plants, rather than vigorous ones, carry large thrips populations, and are also more susceptible to thrips damage. This was demonstrated by the obvious thrips injury in the 1951 Forest Hill field trials, when over the final month irrigation was not used.

After consideration of data from the earlier trials and general field observations, the author (Passlow 1953) stated: "With adequate irrigation and sound farming methods to ensure continuous rapid growth, onions can be produced profitably despite the presence of thrips. Under these conditions the application of suitable insecticides will not appreciably increase yields in either bulb or seed crops." This is supported by results from the later trials, and by further observation in commercial crops.

Irrigation of onion crops in the Lockyer Valley, as carried out over the past decade, has in effect reduced the status of thrips as a pest, and has forestalled the benefits which might have been derived from the use of modern insecticides under the older dry-farming conditions.

V. ACKNOWLEDGEMENTS.

All statistical analyses were carried out by Mr. P. B. McGovern (Biometrician, Division of Plant Industry). Downy mildew was discussed with Mr. T. McKnight (Senior Pathologist, Division of Plant Industry) on several occasions. Mr. G. Hooper (Assistant Entomologist) and Mr. N. Heather (Assistant Experimentalist) conducted the 1955 trials. The Standards Branch of the Department of Agriculture and Stock, carried out the germination tests. Facilities for conducting the trials were provided by several farmers and the Gatton Irrigation Research Station, where threshing machinery was also made available for the seed crop trial.

All this assistance is gratefully acknowledged.

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STUDIES OF ARSENIC SPRAY RESIDUES ON APPLES

By M. BENGSTON, B.Sc. (Assistant Entomologist), and W. R. WINKS, B.Sc. (Senior Toxicologist), Division of Plant Industry.

SUMMARY.

During the 1954-55 and 1955-56 seasons two trials were carried out in the Stanthorpe district to obtain data on arsenic spray residues on apples.

It is evident from these trials that lead arsenate is not weathered appreciably from the fruit, and during the season the gradual reduction in arsenic residue as p.p.m. As_2O_3 is largely the result of fruit growth. One 3 lb./100 gal. spray applied to the variety Granny Smith at a dosage rate of 1¼ gal. per tree in late November resulted in residues of less than 0.6 p.p.m. at early harvest in early January, and at the same dosage rate and timings the mean residue from a double strength spray was 1.46 p.p.m.

I. INTRODUCTION.

In the Stanthorpe district lead arsenate sprays were used for many years in the control of apple pests. Recently, however, an arsenic residue problem has been given some prominence. Although satisfactory alternative sprays are now available for most of the common pests (May and Bengtson 1955), there is a tendency to continue using the old insecticide. The two trials reported in this paper were carried out to obtain data on arsenic spray residues on apples under conditions prevailing in the Stanthorpe district.

In Queensland, the current tolerance limit for arsenic as As_2O_3 is 1·4 p.p.m.

II. MATERIALS.

The following materials were used:—

Lead arsenate.—A powder containing 31 per cent. As_2O_5 as lead arsenate, and 1 per cent. dispersing agent: containing less than 0·5 per cent. water-soluble arsenic compounds.

DDT.—An emulsion concentrate containing 25 per cent. *p,p'* isomer w/v.

Parathion (E605).—An emulsifiable preparation containing 50 per cent. w/v active ingredient.

III. METHODS.

The trials were set out, during the 1954-55 and 1955-56 seasons, as randomised blocks with a single tree of the variety Granny Smith as the plot unit.

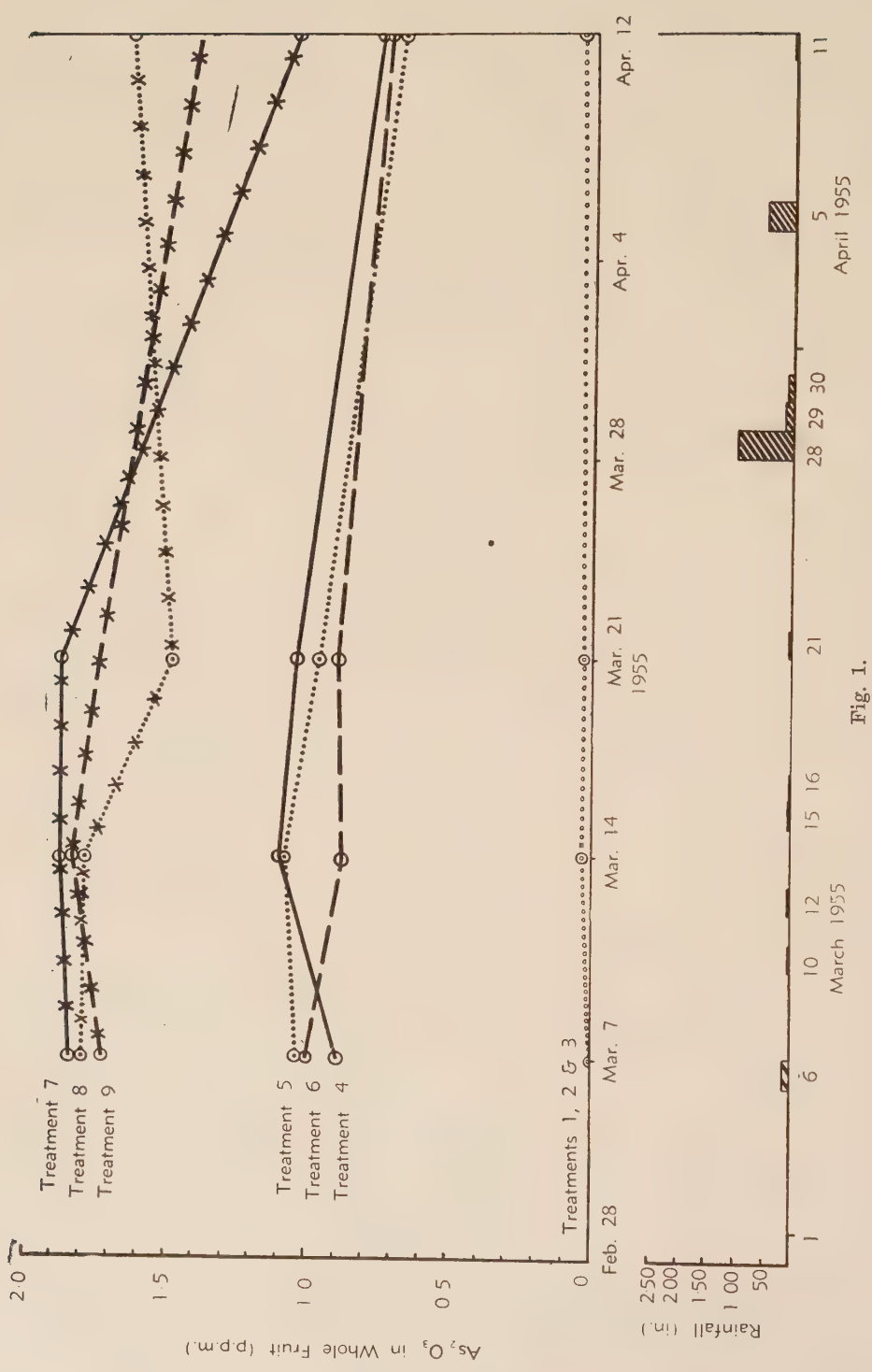

Fig. 1.
Arsenic Residues in Whole Fruit, 1954-55 Season.

Treatment sprays, details of which are given with the results, were formulated with due regard to spray combinations which may be used commercially. These were applied at the rates of 1½ gal. per tree in the first trial and 1¼ gal. per tree in the second, using a small power unit at nozzle pressures of 250 lb. and 200 lb. per sq. in. All programme sprays not containing lead arsenate (May and Bengtson 1955) were applied prior to both trials, and also during the 1955-56 trial, which occupied the greater part of the season.

Samples of 10 fruit were taken at random intervals from each plot. The fruit was picked into a commercial picking bag, and then placed in a brown paper bag for despatch to the laboratory. As far as possible the method of handling fruit was constant.

In the laboratory each sample was weighed before being thinly peeled. The peeled fruit was then weighed, and the difference between the weights was taken as the weight of peel.

Each peel sample was placed in a 600 ml. beaker, and 100 ml. of concentrated nitric acid was added. The beaker was covered with a watch-glass and heated on a water-bath until a homogeneous mixture with little or no stringiness resulted. After cooling, the contents were transferred to a 500 ml. volumetric flask. An aliquot, usually 25 ml., was digested according to the method of Allcroft and Green (1935) and arsenic as As_2O_3 was determined by a standard Gutzeit method. Representative samples of flesh were treated similarly.

In the statistical analyses the results from treatments not including lead arsenate were excluded, since the residues in such cases were very small or zero. The results from the other treatments were analysed in terms of a logarithmic transform. Treatment averages, in equivalent p.p.m. in peel and whole fruit, are given in Tables 1, 2, 4 and 5; and for whole fruit only are shown graphically with the rainfall records in Figs. 1 and 2.

The product of average fruit size and arsenical residue has been used as a measure of arsenical load per fruit.

Analyses of variance were carried out, using a logarithmic transformation after excluding the zero values.

Further details of each trial are also given with the results.

IV. RESULTS.

(1) 1954-55 Season.

This trial was a 9 x 4 randomised block and treatments were applied on Feb. 28, 1954. The original intention was to determine DDT residues also but this could not be accomplished with the facilities available.

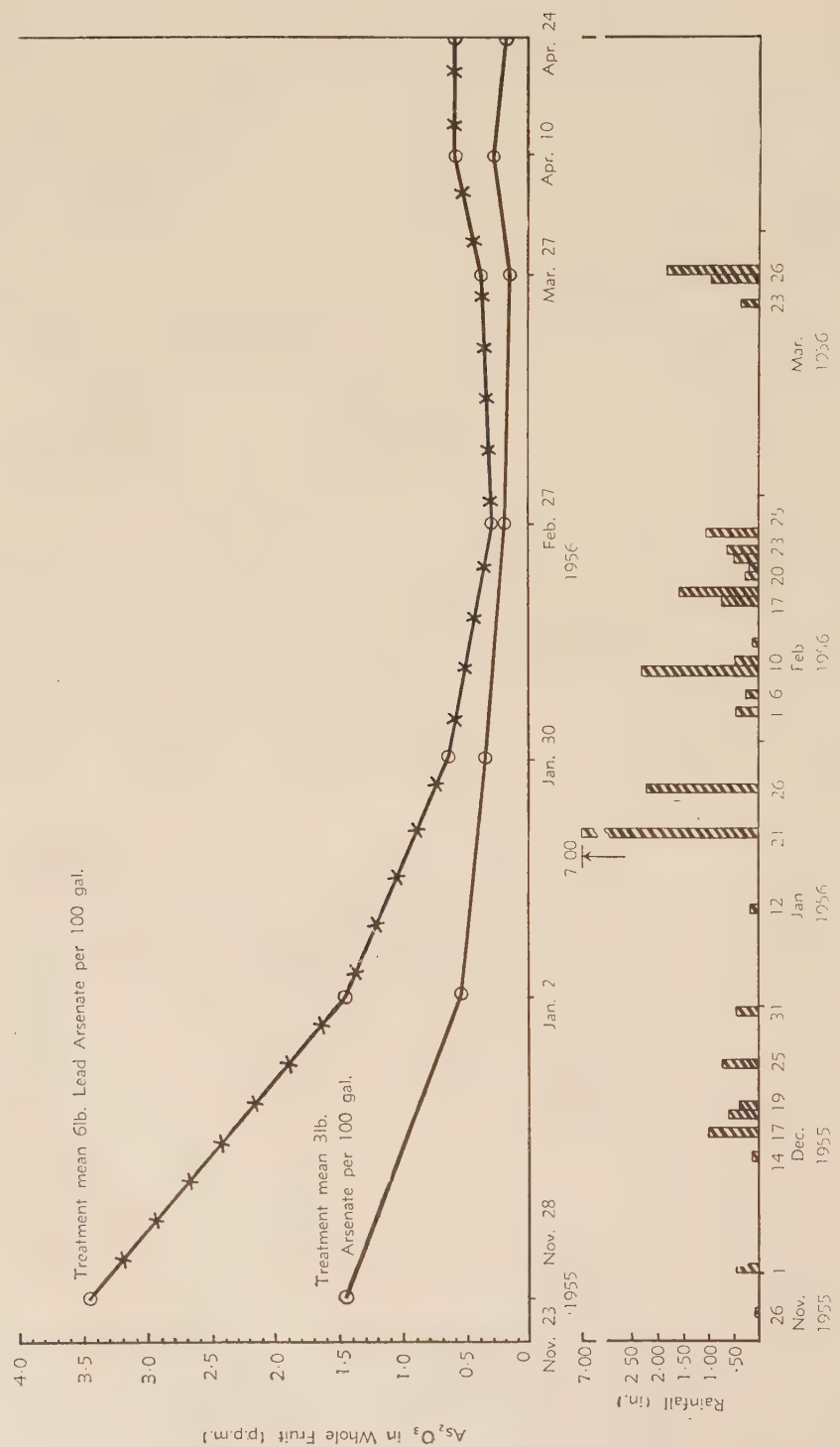
Treatment mean 6lb. Lead Arsenate per 100 gal.
Treatment mean 3lb. Arsenate per 100 gal.
As2O3 in Whole Fruit (p.p.m.)
Rainfall (in.)
Nov. 23 Nov. 28 Jan. 2 Jan. 30 Feb. 27 Mar. 27 Apr. 10 Apr. 24
1955 1956
26 1 14 17 19 25 31 12 21 26 1 6 10 17 20 23 25 23 26
Nov. Dec. Jan Feb Mar.
1955 1955 1956 1956 1956
7·00

Fig. 2.

Arsenic Residues in Whole Fruit, 1955-56 Season.

Treatments were as follows:—

(1) Untreated.

(2) DDT 0·1 per cent.

(3) DDT 0·2 per cent.

(4) Lead arsenate 3 lb./100 gal.

(5) Lead arsenate 3 lb./100 gal. + DDT 0·1 per cent.

(6) Lead arsenate 3 lb./100 gal. + DDT 0·2 per cent.

(7) Lead arsenate 6 lb./100 gal.

(8) Lead arsenate 6 lb./100 gal. + DDT 0·1 per cent.

(9) Lead arsenate 6 lb./100 gal. + DDT 0·2 per cent.

Strengths of DDT sprays are given as percentages of *p,p'* isomer.

The results appear in Tables 1–3.

Table 1.

As_2O_3 IN PEEL (p.p.m.).

Treatment.		Sampling Date.			
DDT	Lead arsenate.	Mar. 7.	Mar. 14.	Mar. 21.	Apr. 12.
0	3 lb./100 gal.	7·50	9·75	9·84	7·20
0·1%	3 lb./100 gal.	8·85	9·70	9·01	6·22
0·2%	3 lb./100 gal.	8·79	8·09	8·53	7·30
Average		8·35	9·15	9·11	6·89
0	6 lb./100 gal.	15·98	16·23	17·23	9·46
0·1%	6 lb./100 gal.	15·46	16·61	13·85	15·39
0·2%	6 lb./100 gal.	14·00	16·70	16·92	13·48
Average		15·12	16·51	15·92	12·51
Average weight of peel (g.)..		15·8	15·9	16·6	19·9

No arsenic was found in the flesh of the apples.

On all sampling dates the differences between the levels of lead arsenate were highly significant, the residues from the 6 lb./100 gal. spray being about 1·8 times those of the 3 lb./100 gal. application. There is no evidence that the presence of DDT in the spray affected arsenic residues. The arsenic load did not decrease over the period of 36 days.

Forty-three days after applying one 6 lb./100 gal. spray at the rate of 1½ gal. per tree the arsenic residue was only slightly under the allowable 1·4 p.p.m.

Table 2.

As_2O_3 IN WHOLE FRUIT (p.p.m.).

Treatment.		Sampling Date.			
DDT	Lead arsenate.	Mar. 7.	Mar. 14.	Mar. 21.	Apr. 12.
0	3 lb./100 gal.	·89	1·10	1·05	·75
0·1%	3 lb./100 gal.	1·04	1·09	·97	·68
0·2%	3 lb./100 gal.	1·01	·89	·91	·73
Average		·98	1·03	·98	·72
0	6 lb./100 gal.	1·85	1·88	1·88	1·06
0·1%	6 lb./100 gal.	1·80	1·80	1·49	1·63
0·2%	6 lb./100 gal.	1·73	1·84	1·75	1·40
Average		1·80	1·84	1·70	1·34
Average weight of fruit (g.)		137·0	143·5	155·5	187·2

Table 3.

AVERAGE ARSENICAL LOAD PER FRUIT (μg.).

Lead arsenate Spray Concentration.	Sampling Date.			
	Mar. 7.	Mar. 14.	Mar. 21.	Apr. 12.
3 lb./100 gal.	134	144	152	135
6 lb./100 gal.	247	273	273	267

(2) 1955-56 Season.

This trial was a 6 x 4 randomised block and treatments were applied on Nov. 23 and 24.

Treatments were as follows:

(1) Untreated.

(2) Parathion 0·01 per cent. + DDT 0·1 per cent.

(3) Parathion 0·01 per cent. + DDT 0·1 per cent. + lead arsenate 3 lb./100 gal.

(4) Parathion 0·01 per cent. + DDT 0·1 per cent. + lead arsenate 6 lb./100 gal.

(5) Lead arsenate 3 lb./100 gal. followed in 24 hours by parathion 0·01 per cent. + DDT 0·1 per cent.

(6) Lead arsenate 6 lb./100 gal. followed in 24 hours by parathion 0·01 per cent. + DDT 0·1 per cent.

Strengths of emulsion sprays are given in percentages of active ingredients.

The results are given in Tables 4-6.

Table 4.

As_2O_3 IN PEEL (p.p.m.).

Sampling Date.	3 lb./100 gal. Treatments.			6 lb./100 gal. Treatments.		
	S*.	A†.	Mean.	S*.	A†.	Mean.
Nov. 28	7·36	6·70	7·02	17·18	15·14	16·11
Jan. 2	3·53	3·43	3·48	8·67	8·95	8·81
Jan. 30	2·82	2·27	2·53	4·67	4·70	4·68
Feb. 27	1·29	1·45	1·37	2·33	1·95	2·15
Mar. 27	0·79	1·49	1·08	3·70	2·44	3·01
Apr. 10	2·08	2·01	2·05	4·59	4·23	4·41
Apr. 24	1·45	1·55	1·50	4·56	4·82	4·69

* S=0·01% parathion and 0·1% DDT applied with the lead arsenate.
† A=0·01% parathion and 0·1% DDT applied 24 hours after the lead arsenate.

Table 5.

As_2O_3 IN WHOLE FRUIT (p.p.m.).

Sampling Date.	3 lb./100 gal. Treatments.			6 lb./100 gal. Treatments.		
	S*.	A†.	Mean.	S*.	A†.	Mean.
Nov. 28	1·48	1·43	1·45	3·50	3·36	3·44
Jan. 2	0·55	0·58	0·56	1·44	1·48	1·46
Jan. 30	0·40	0·32	0·36	0·65	0·62	0·64
Feb. 27	0·19	0·20	0·19	0·33	0·27	0·30
Mar. 27	0·11	0·19	0·14	0·46	0·32	0·38
Apr. 10	0·30	0·26	0·28	0·62	0·56	0·59
Apr. 24	0·18	0·19	0·19	0·59	0·59	0·59

* S=0·01% parathion and 0·1% DDT applied with the lead arsenate.
† A=0·01% parathion and 0·1% DDT applied 24 hours after the lead arsenate.

Table 6.

AVERAGE ARSENICAL LOAD PER FRUIT (μg.).

Sampling Date.	Lead arsenate Spray Concentration.	
	3 lb./100 gal.	6 lb./100 gal.
Nov. 28	57	124
Jan. 2	43	111
Jan. 30	45	77
Feb. 27	30	46
Mar. 27	28	75
Apr. 10	56	115
Apr. 24	38	118

No arsenic was found in the flesh of the apples.

These results are in general similar to those from the earlier trial. Some residue values, however, are distinctly low but these do not detract from the general conclusions: the samples concerned were taken under wet orchard conditions (see Fig. 2).

V. DISCUSSION.

It is evident from these trials that lead arsenate is not weathered appreciably from the fruit, and during the season the gradual reduction in arsenic residues as p.p.m. is largely due to fruit growth.

In Stanthorpe apple orchards the calyx spray is applied in October, and the spray programme continues with applications in early November (about two weeks after the calyx spray), late November, mid-December, early to mid-January and late January to early February. District harvesting of some cooking varieties may commence in early December, and the variety Granny Smith may be picked as cookers in early January.

Under the conditions of these trials, using the variety Granny Smith, one lead arsenate spray of the recommended commercial strength (3 lb./100 gal.) applied in late November resulted at early harvest time in residues of less than 0·6 p.p.m., and with the same timings the residue from a double-strength spray was 1·46 p.p.m. Fruit growth of the earlier varieties is comparatively rapid, and a corresponding reduction in residues (p.p.m.) would occur before harvesting. Further use of lead arsenate after late November, however, would be dangerous so far as the residue tolerance limit for arsenic is concerned.

May and Bengtson (1955) warned that to avoid undesirable residues lead arsenate should not be used after early November. This allows an increased safety margin for differences which may occur between experimental and commercial arsenic residues.

VI. ACKNOWLEDGEMENTS.

Facilities for conducting these trials were provided by orchardists, and several officers of this Department at Stanthorpe assisted with spraying and preparation of fruit samples. All statistical analyses were carried out by Mr. P. B. McGovern, Biometrician, Division of Plant Industry.

This assistance is gratefully acknowledged.

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PAPAW ROOT ROT CAUSED BY *PHYTOPHTHORA PALMIVORA* BUTL.

By D. S. Teakle, B.Agr.Sc., Assistant Pathologist, Science Branch.

SUMMARY.

A severe root rot of papaw (Carica papaya **Gaertn.) in Queensland is caused by** Phytophthora palmivora **Butl.**

Waterlogging is an important predisposing factor in the occurrence of the disease.

In the Brisbane area, soil temperatures are favourable for growth and sporulation of P. palmivora, **except during June, July and August.**

Field evidence suggests that crop rotation reduces the severity of attack.

P. palmivora **isolated from roots proved capable of rotting green papaw fruit, but a similar fruit rot has not been found naturally in Queensland.**

I. INTRODUCTION.

In April 1955 an outbreak of root rot destroyed a 1-year-old planting of papaws near Brisbane, in the south-east of Queensland. Subsequently other outbreaks occurred in the same district, and during 1955 and 1956 losses in this area exceeded 8,000 plants. Further severe losses were experienced near Mackay, in central coastal Queensland.

Root rot of papaws is not new to Queensland, though apparently it was unusually severe in 1955 and 1956. Over 20 years ago Simmonds (1934) isolated a phycomycete from a stem and root rot of papaws and proved its pathogenicity. This organism was in 1935 identified by S. F. Ashby of the Imperial Mycological Institute as *Pythium ultimum* Trow and since then most of the root rot in Queensland has been attributed to this and other species of *Pythium* (Simmonds 1937; Da Costa 1944). Other species of *Pythium* which have recently been isolated from rotting papaw roots are *P. debaryanum* Hesse, *P. oligandrum* Drechsl., *P. vexans* de Bary, *P. irregulare* Buism., *P. spinosum* Saw., and *P. aphanidermatum* (Eds.) Fitzp. Proof of the pathogenicity of these isolates has been attempted only in the case of *P. vexans* and this instance is discussed below.

In other countries species of *Pythium* and *Phytophthora* comprise the characteristic fungus flora associated with papaw root rot. Middleton (1943) listed nine species of *Pythium* from papaw while three species of *Phytophthora* have been recorded from this host in nature. *P. cinnamomi* Rands has been observed from roots only (Bazán de Segura 1951); *P. parasitica* Dast. and *P. palmivora* may attack the roots, stems and fruit (Park 1932; Thompson 1940; Parris 1942).

II. SYMPTOMS.

In the outbreaks of root rot investigated, the symptoms were identical with those described by Wager (1931) as typical of the disease. The leaves turn yellow, wilt, hang limply around the trunk and then fall; eventually only a few small leaves are left at the apex of the tree. Examination of the roots of plants in early stages of infection reveals that generally the rot originates

Fig. 1.

Papaw Plantation Affected by Root Rot. Note the severe losses associated with the depression. Two plants in the foreground show early symptoms.

on the smaller laterals. In the later stages the tap-root also is involved and the whole root system becomes reduced to a soft, shredded, evil-smelling, brown mass. Severely affected plants are easily blown over by strong winds.

Under some conditions these symptoms may be expressed in a matter of days; under others, symptoms develop slowly over weeks or months. Often slightly affected plants make temporary recovery but later succumb to the disease.

III. ETIOLOGY.

Initial isolations on water agar from plants in advanced stages of attack showed that *Pythium vexans* was consistently associated with the rot. However, microscopic examination of pieces of infected root tissue placed overnight in sterile water revealed the presence of large papillate sporangia distinct from the smaller non-papillate sporangia of *P. vexans.* The larger sporangia resembled those of certain species of *Phytophthora,* and to confirm this, isolations from soil were carried out by the apple technique devised by Campbell (1949) for *P. cinnamomi.* These isolations showed that a *Phytophthora,* subsequently identified as *P. palmivora,* was consistently present in soil near affected plants. Later, *P. palmivora* was isolated on water agar from papaw roots in an early stage of decay.

(1) Papaw Inoculations.

In order to determine the relative pathogenicity of *Phytophthora palmivora* and *Pythium vexans* to papaw plants, these fungi were subjected to a glasshouse inoculation test. Also included for comparison were a species of *Fusarium* isolated from rotting papaw rootlets on healthy plants and *Phytophthora cinnamomi* obtained from avocado roots.

On July 11, 1955, each of the four fungi was inoculated into three potted papaw plants 18 in. high; three plants were left uninoculated as controls. Soil was scraped away from the base of each plant, which was scarified with a scalpel. A block ($\frac{1}{2}$-in. square) of an actively growing potato dextrose agar culture of the fungus was placed against the damaged plant surface, the soil returned and the pot watered immediately. Watering was continued to keep the plants growing normally.

The three plants inoculated with *P. palmivora* exhibited root rot symptoms after 9, 16, and 23 days respectively (Fig. 2). A severe rot commenced at ground level and gradually extended down to the root system and some six inches up the stem. On the other hand, plants inoculated with *P. vexans, Fusarium* sp., and *P. cinnamomi,* and uninoculated control plants, were still healthy on Oct. 27, about 14 weeks after commencement of the experiment. Re-isolations from the margin of rotting areas confirmed that *P. palmivora* was the pathogenic organism.

Fig. 2.

Progressive Development of Symptoms 23 days after Inoculation with *P. palmivora*. Plant 4 Uninoculated.

(2) Waterlogging Experiment.

In preliminary experiments it had been found that only when *P. palmivora* was placed in contact with the injured base of the papaw plant did root rot symptoms develop. Uninjured plants growing in inoculated soil remained healthy, as also did plants which had their surface lateral roots slashed with a scalpel. Apparently some other predisposing factor was necessary for development of severe root rot. Field observations had indicated the importance of waterlogging in the occurrence of outbreaks of root rot. To study the effect of this factor a further experiment was carried out, using the healthy plants previously inoculated with *P. vexans* and the three uninoculated controls.

On Oct. 27, two plants in each series were inoculated with *P. palmivora* on cornmeal-sand medium, while sterile cornmeal-sand was added to the third. The plants were watered immediately, and subsequent watering was carried out so as to keep the plants growing normally. No root rot symptoms developed up to Dec. 9, six weeks after inoculation.

On this date, the pots were submerged in water so that the bases of the plants were covered. Three days later, the pots were removed and allowed to drain. Within two days of removal from the water, all plants, including the controls, showed early symptoms of root rot—that is, the lower leaves

Fig. 3.

Effect of Three Days' Waterlogging on Papaw Plants Growing in Soil Inoculated with *P. palmivora* (Plants 1 and 3) and Uninoculated Soil (Plant 2).

yellowed, wilted and fell. However, subsequent observation revealed that the rate of defoliation was greater with those plants inoculated with *P. palmivora* than with control plants. After three weeks the latter still had two large healthy leaves while inoculated plants were completely leafless (Fig. 3).

On Dec. 29, all plants were removed from their pots, the amount of root rot assessed, and isolations made to determine associated organisms. The results are given in Table 1. Severe root rotting occurred only when P. *palmivora* was present during waterlogging.

Table 1.

Effect of Three Days' Waterlogging on Root Rot Symptoms.

Original Crown Inoculation 11–7–55.	Subsequent Soil Inoculation 27–10–55.	Healthy Leaves 29–12–55.	Rot Symptoms 29–12–55.			Pythiaceous Fungus Reisolated.
			Laterals.	Taproot.	Base.	
P. vexans ..	*P. palmivora*	0	Severe	Severe	Severe	*P. palmivora*
P. vexans ..	*P. palmivora*	0	Severe	Severe	Severe	*P. palmivora*
P. vexans ..	Nil	2	Moderate	Moderate	Slight	*P. vexans*
Nil	*P. palmivora*	0	Severe	Moderate	Severe	*P. palmivora*
Nil	*P. palmivora*	0	Severe	Severe	Severe	*P. palmivora*
Nil	Nil	2	Slight	Slight	Absent	Nil

(3) Papaw Fruit Inoculations.

While *P. palmivora* has been shown to be responsible for severe outbreaks of root rot in Queensland, there has been no record of the fruit rot reported from the Pacific islands of Fiji (Campbell 1925; Simmonds 1925) and Samoa (Smith 1955). Inoculations were therefore carried out to determine if the root rot isolate of *P. palmivora* was a potential fruit pathogen.

Eight immature papaw fruit were surface sterilized with 95 per cent. ethyl alcohol. On each fruit three inoculation sites were chosen and on half of the fruit these were lacerated with a scalpel. Inoculation of two sites on each fruit was carried out by applying blocks from the margin of a P.D.A. culture of *P. palmivora*. After inoculation the fruit was placed in a moist chamber for seven days and then examined.

P. palmivora was pathogenic to wounded green papaws in all eight cases. The symptoms of the rot were a firm, slightly yellowish rot of the white flesh, which extended about three inches across the fruit in five days. The surface of the lesion became slightly wrinkled and covered with a powdery material (Fig. 4), which was found to consist of masses of chlamydospores. In the case of the intact inoculation sites, infection was secured in two out of eight inoculations. Uninoculated sites remained unaffected.

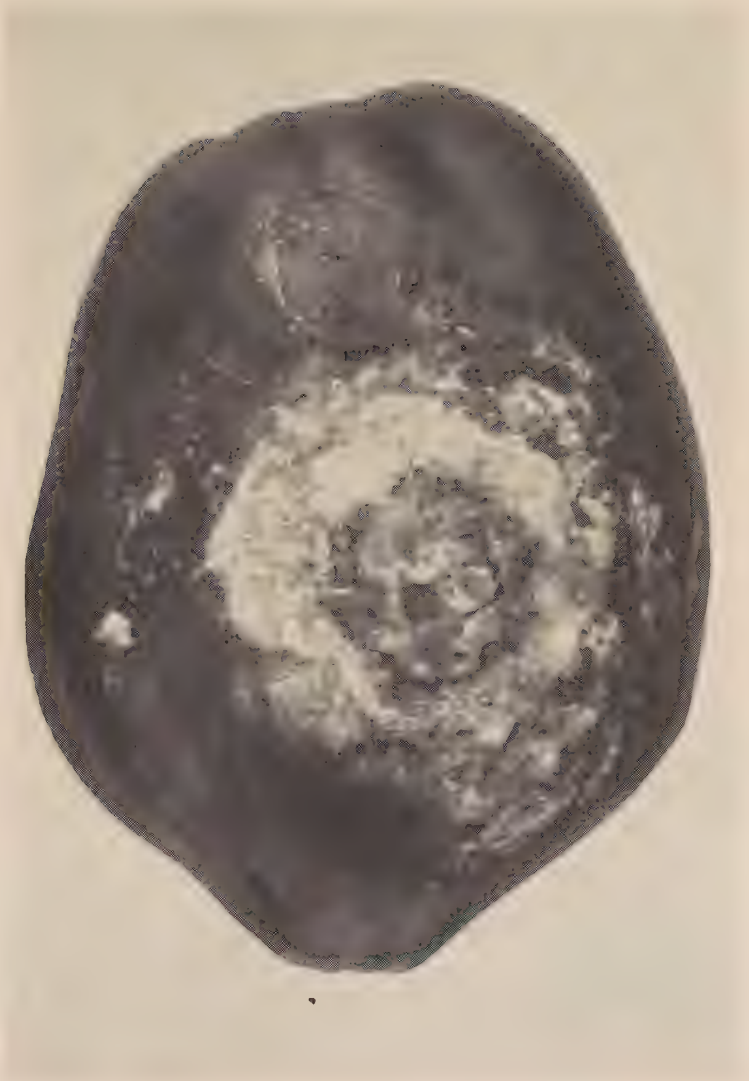

Fig. 4.

Green Papaw Fruit Inoculated with *P. palmivora* Isolated from Rotted Roots.

These results with *P. palmivora* agree with those obtained by Parris (1942) with *P. parasitica*. This author found that *P. parasitica* is essentially a wound parasite, but will infect wound-free fruits, stems, roots and leaves if they are kept in a moist atmosphere following inoculation.

IV. PREDISPOSING CONDITIONS.

The available evidence indicates that at least five factors influence the occurrence of papaw root rot. These are soil moisture, temperature, damage to the roots, age of the plants, and previous cropping history of the soil.

(1) Soil Moisture.

Wager (1931) and Simmonds (1937) stated that excessive soil moisture is a common predisposing condition in the occurrence of papaw root rot and base rot, and that plantings on soils with impeded drainage are particularly liable to attack. These claims are borne out by the waterlogging experiment described above and by numerous field observations. In natural occurrences, it is common for the disease to originate in the gullies, or in the poorer drained portions of a plantation where water accumulates, and to spread out to adjacent areas if wet weather continues (Fig. 1).

Soil texture influences the severity of the disease, apparently by its effect on internal drainage. Clay soils appear to be more subject to root rot than sandy soils, although where heavy subsoils occur beneath the latter the taproot may rot away, leaving the plant to subsist on surface laterals.

(2) Temperature.

According to Ashby (1929), *Phytophthora palmivora* is a tropical species which has an optimum temperature for mycelial growth on agar media of 27–28 deg. C., and which forms sporangia freely at temperatures between 20 deg. and 30 deg. C. in two or three days. On this information it would be expected that soil temperatures between 20 deg. and 30 deg. C. would be conducive to attacks of root rot.

To determine during which months of the year root rot is likely to be a problem in the Brisbane area, the mean monthly temperatures for soil one foot below ground level, obtained through the courtesy of the Commonwealth Meteorological Bureau, were compared with multiple temperature incubator data on the growth of *P. palmivora* on cornmeal agar.

Table 2.

Comparison of Mean Monthly Soil Temperatures with the Growth of *P. palmivora* at the Corresponding Temperatures.

Month.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean monthly soil temperature (°C.) at 1 ft.	28	27	26	23	20	17	15	17	20	23	26	27
Growth in mm. in 24 hours at corresponding temperature	10	10	10	8	7	5	3	5	7	8	10	10

Table 2 shows that usually only during June, July and August are temperatures so low that mycelial growth of *P. palmivora* is reduced by half or more of the maximum.

In an attempt to determine the effect of temperature on sporulation of *P. palmivora* the following procedure was carried out:—

Three millilitres of sterile water was placed in each of 20 petri dishes (10 cm. diameter) and into each of these were placed five plugs (6 mm. diameter) taken from the margins of young P.D.A. cultures of the fungus. The petri dish cultures were incubated for three days over a range of 20 temperatures between 7 deg. C. and 43 deg. C., and then examined with the low power of a monocular microscope for the occurrence of sporulation. The results are given in Table 3.

Table 3.

Temperature Requirements for Sporulation of *P. palmivora.*

Temperature (°C.).	7–17.	18–23.	24–27.	28.	30–43.
Sporulation	Absent	Slight*	Moderate†	Slight*	Absent

* Approximately 1–3 chlamydospores and sporangia per field.
† Approximately 4–12 chlamydospores and sporangia per field.

The months of June, July and August, with soil temperatures below 18 deg. C., and possibly May and September as well, appear unfavourable for sporulation of the fungus. It has been claimed by growers that root rot is less severe during the cold months.

Severe outbreaks of the disease in the Brisbane area have been most frequent in the months of March and April, which, apart from being wet, have temperatures near the optimum for growth and sporulation of *P. palmivora.*

(3) Damage to the Roots.

Phytophthora parasitica was found by Parris (1942) to be essentially a wound parasite of the papaw, and this also appears to be the case with the closely related *P. palmivora.*

In a preliminary pathogenicity trial, *P. palmivora* failed to cause visible rot when inoculated into soil near unwounded papaw plants. Under normal growing conditions, only when inoculum was placed against the damaged base of the stem, as described for the first experiment, did plants develop appreciable rot and eventually die.

It would be expected that strong winds, by severely buffeting plants, would cause root damage and predispose plants to attack, if other factors favouring fungus activity operated. Such is apparently the case during periods of cyclonic weather, when gale-force winds and heavy prolonged rainfall coincide. It is after such periods that the most severe outbreaks have been recorded.

(4) Age of Plants.

Young trees have been found to be more subject to root rot than older trees. Large trees, besides having larger and more extensive root systems than smaller trees, appear to have larger food reserves and a better opportunity of re-establishing themselves after losing a proportion of their roots.

(5) Crop Rotation.

Crop rotation has long been recognised as a common and successful procedure for control of some soil-borne diseases (Garrett 1944), and evidence collected in this investigation indicates that papaw root rot, also, is amenable to control by this means.

In one instance, an old papaw plantation was cut out, and, together with an adjacent area which had carried volunteer grasses and weeds for several years, planted with young papaws. A year later, following a cyclone, plants on the old papaw land were severely attacked by root rot, while those on previously spelled land initially displayed no symptoms of disease. At a distance, the margin between the two sections could be seen as a straight line. The reason for this difference may have been a build-up of *P. palmivora* on the dying roots of the previous papaw planting.

Further, little success has attended replanting of sites where papaws have recently died from root rot. In one instance it was reported that four successive replant crops had died out in quick succession over a wet period. This furnishes additional evidence of the adverse effect of replanting land without adequate crop rotation.

V. CONTROL.

No experiments on the control of papaw root rot on a field scale have been conducted. It might be expected that the installation of subsurface drainage would considerably reduce the risk of waterlogging and the associated root rot, but the cost of this would be too high for most growers. The more practicable surface drainage should be practised.

Crop rotation appears to be effective in reducing the initial intensity of infection but does not provide protection against infection under conditions of prolonged waterlogging.

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PINEAPPLE FERTILIZER INVESTIGATIONS IN SOUTH-EASTERN QUEENSLAND

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SUMMARY.

Fertilizer trials were carried out during 1951-1954 on four soil types differing mainly in their potassium content. Four applications per annum were made into the base leaves of the plants.

There were only limited responses to nitrogen, and only one trial produced significant increases in yield of the plant crop from progressive increments. In this case the yield increased from 23.8 tons per acre with 100 lb. of nitrogen to 25.2 tons with 300 lb. It is concluded, based on growth measurements, that the requirements of the crop up to the time of flowering do not exceed 100 lb. of nitrogen per year, but that the rate may be increased with advantage during the post-flowering period. The higher rates of nitrogen applied after harvesting of the plant crop promoted suckering, which resulted in progressive yield increases up to 5.9 tons per acre in the ratoon crop.

There were no responses to phosphorus in either plant growth or yield of the plant crop in any of the trials. There was, however, an unexplained yield response in the ratoon crop in one of the trials.

The response to potassium was most marked, and the results indicate that pineapples grown on soils below 0.2 m-equiv. of replaceable potassium per 100 g. require potassium at the rate of at least 166 lb. per acre per year. There was virtually no response to added potassium on soils with a replaceable potassium content of 0.5 m-equiv. and over per 100 g.

Fruit quality determinations showed that potassium tends to increase both sugars and acids, whereas nitrogen has the reverse effect.

I. INTRODUCTION.

In Queensland, fertilizing practices in pineapples have for many years been based on the use of a 10:6:10 mixture, alternating with sulphate of ammonia and applied at regular intervals and at a fixed rate irrespective of the soil type. This schedule supplies approximately 300 lb. of N, 36 lb. of P and 116 lb. of K per acre per annum. Since the soils on which pineapples are grown vary greatly in chemical composition, it has been felt for some time that adherence to a fixed fertilizing schedule would provide inadequate amounts of nutrients for some soils or entail luxury feeding in other cases. These investigations were, therefore, undertaken with the object of determining a basis for more efficient fertilizing on representative soil types, having regard to their chemical composition.

II. LOCATION OF TRIALS.

The trials reported herein were laid down in the autumn of 1951 on four soil types of the North Coast, and on land which had previously been cropped for a number of years. They were as follows:—

No. 1.—*Light-brown Sandy Loam* (Glasshouse) derived from sandstone, a common soil type in the Beerwah-Glasshouse district.

No. 2.—*Red-brown Loam* (Flaxton) of basaltic origin, and the typical soil of the Blackall Range.

No. 3.—*Dark-brown Clay Loam* (Dagun) derived from a manganiferous quartzite and allied rocks, and characteristic of much of the Mary Valley (near Gympie). Similar soils also occur in the Yeppoon district of Central Queensland.

No. 4.—*Dark-grey Clay Loam* (Maroochy Experiment Station, Nambour) derived from sandstone and intermediate igneous rocks, and a less common soil type on the North Coast.

Analyses of composite soil samples obtained prior to the inception of the trials are set out in Table 1.

Table 1.

Chemical Analyses of Soils from Trial Areas.

Soil.	pH.	Total N (%).	*Available P_2O_5 (p.p.m.).	Replaceable Bases (m-equiv. per 100 g.).	
				K.	Total.
No. 1	5·1	0·06	80	0·18	2·83
No. 2	4·4	0·34	85	0·18	2·91
No. 3	5·1	0·19	80	0·50	10·83
No. 4	5·4	0·42	140	0·60	13·77

* Estimated by the Queensland Bureau of Sugar Experiment Stations Method.

Nitrogen was variable and not closely related to soil type, being extremely low in the sandy loam (No. 1). All samples were much higher in available P_2O_5 than in soils in the virgin state, as reported by Vallance (1938), who found that the level rarely exceeded 10 p.p.m. of available P_2O_5 (Truog's method). This is presumed to be the result of a build-up of phosphate from previous fertilizer applications, since in all cases the land had been under pineapples for many years. There were marked differences in the potassium content of the soils, the two clay loams being considerably higher in replaceable potassium than the lighter soils.

III. EXPERIMENTAL DESIGN AND TREATMENTS.

The trials were laid out as 3 x 3 x 3 factorials, with two absolute replications at each centre. Individual plots consisted of paired rows 40 ft. long, containing 80 plants, except in Trial 1, which had 84 plants in 42 ft. rows. No border rows were provided between adjacent rows, but buffers 5 ft. or more in length were allowed between adjoining plots in the same row.

Magistad and Farden (1934) advocated larger plots for pineapples, but practical considerations, which limited the total area of the trials to half an acre each, necessitated the use of the smaller plot size. For the same reason, border rows were omitted on the ground that application of the fertilizer

directly into the basal leaves would limit lateral movement of nutrients between plots. This evidently did not introduce a large source of error, since the standard error per plot ranged from 2 to 8 per cent. of the general mean and exceeded 5 per cent. in only one case.

(1) Fertilizer Levels.

In view of the normal seasonal variation in soil nitrogen, there were no "nil" treatments and the same three levels of nitrogen were included in all trials. In the case of phosphorus and potassium, however, the levels were varied according to the soil analyses. Details of the experimental levels in terms of total per acre per annum are given in Table 2.

Table 2.

EXPERIMENTAL FERTILIZER LEVELS (LB./AC./ANNUM).

N.		P.		K.	
N1	.. 100	PO	.. Nil	KO	.. Nil
N2	.. 200	P1	.. 9	K1	.. 41
N2	.. 300	P2	.. 18	K2	.. 83
		P3	.. 36	K3	.. 166

Nitrogen was supplied as sulphate of ammonia, phosphorus as superphosphate, and potassium as sulphate of potash. To facilitate uniform application the 27 mixtures were made up to a standard volume by the addition, where necessary, of a fine sand "filler."

In Trials 1, 2 and 3, where available P_2O_5 was of the order of 80 p.p.m., the levels of P0, P2 and P3 were used; P0, P1 and P2 were used in Trial 4, where available P_2O_5 was 140 p.p.m. The potassium levels in Trials 1 and 2, with replaceable K at 0·18 m-equiv. per 100 g., were K0, K2 and K3, and K0, K1 and K2 were used in Trials 3 and 4, where replaceable K was 0·50 and 0·60 m-equiv. per 100 g. respectively.

(2) Method and Times of Application of Fertilizer.

All fertilizer mixtures were applied into the basal leaves of the plants, which is the normal practice in the crop. A measured volume of the appropriate mixture was applied with a small metal scoop designed to hold the requisite quantity for a single plant.

Over the period of the plant crop cycle, which occupied a little under two years, seven fertilizer applications were made, as follows:—

1951: Mid-April, early September and early December;

1952: Early February, late April, early September and mid-November.

Trial 4, which was carried through to the ratoon crop, received a further four applications during 1953 at times corresponding to those for 1952.

(3) Cultural Methods.

Tops (or crowns) were used as planting material on account of their known superiority to slips and suckers in uniformity of behaviour. To further reduce plant variability the tops were graded for size on a weight basis, allowing a tolerance of ±1 oz. within a replication. The standard planting layout was followed—i.e., plants spaced 12 in. apart in paired rows 2 ft. apart, the paired rows (or beds) being 6 ft. apart, centre to centre.

Planting was carried out by hand and took place under favourable conditions in March 1951. All trials were planted within a few days of one another. Good rain fell at Glasshouse (Trial 1) and Maroochy Experiment Station (Trial 4) immediately after planting. As a result, the plants in these trials established quickly and made considerable growth before winter. At the other two centres the trials did not have the same initial advantage, but were reasonably well established before winter. In Trial 2 (Flaxton) the cooler conditions encountered in this locality (elevation 1,000 ft.) resulted in slower growth than elsewhere. At Dagun (Trial 3) a long dry period in the spring and early summer of 1951 affected growth and the crop was correspondingly backward.

Standard cultural methods were followed in handling the crop, weeds being controlled by the use of PCP sprays. At Dagun, ferrous sulphate sprays were applied regularly to correct manganese-induced iron deficiency, which occurs on this soil.

One of the common difficulties in assessing yields in pineapples is irregularity in flowering of otherwise apparently uniform plants. To overcome this, artificial flower induction with alpha-napthalene acetic acid (ANA) was employed to produce uniform flowering for a summer crop. Accordingly, ANA at 10 p.p.m. was introduced into the hearts of the plants in May 1952 in all but the Dagun trial. In this case, treatment was deferred until October, by which time 10 per cent. of the plants had already flowered naturally; these were disregarded, yields being based on the main crop in the autumn. In the one trial (No. 4) which was carried through to the ratoon, ANA treatment was applied again in May 1953 and resulted in a summer ratoon crop.

IV. SEASONAL GROWTH RESPONSES.

Seasonal responses to treatments were estimated by means of a series of growth measurements over intervals corresponding to the periods between successive fertilizer applications. These were not commenced until the spring following planting, and were discontinued at or about flowering, when the plants entered the reproductive phase.

(1) Methods of Growth Measurement.

In these trials, the growth of the immature leaves in the central part of the plant was used as an index of the growth of the whole plant. A leaf approximately 30 cm. in length was selected as the first datum leaf and measured at the beginning and the end of a particular growth period to ascertain its increase in area. At the end of the first growth period a second leaf was chosen on the same basis, and its increase in area over the ensuing period calculated, and so on. At the end of each period a count was also made of the number of leaves intermediate between the original and the second datum leaf, these being the leaves which had elongated beyond 30 cm. within the period.

The increase in area of this group of leaves was taken to be proportional to that of the datum leaf, and the increase in total leaf area of this part of the plant was calculated as—

$$\frac{\text{Datum leaf increase} \times \text{No. of intermediate leaves}}{2}$$

For the purposes of discussion this has been designated the "growth increment."

Leaf length was measured by gently inserting a slender graduated scale between the leaf bases and reading off the length at the leaf tip. Width was measured at about one-third the distance from the base, where the pineapple

Table 3.

Growth Increments (sq. cm./plant), October–December, 1951.

Treatment.	Glasshouse. 17/10/51 to 5/12/51.	Dagun. 7/11/51 to 13/12/51.	M.E.S. 15/11/51 to 12/12/51.
N1	96	65	92
N2	109	77	107
N3	104	69	102
P0	104	70	105
P1	..	..	95
P2	106	73	102
P3	99	68	..
K0	91	69	95
K1	..	68	96
K2	105	74	111
K3	113	..	..
Mean	103	70	100
Necessary differences for significance 5%	20	14	24
Necessary differences for significance 1%	28	19	..

leaf is more or less parallel-sided. For this purpose a light flexible metal scale, which conformed to the curvature of the leaf blade, was used. The datum leaves were identified by marking the tips with paints of different colours to facilitate their subsequent recognition.

Measurements were based on samples of four plants per plot, the size of the sample being dictated by practical considerations in handling this work. Larger samples would, no doubt, have reduced the high sampling variance of the data and have made it possible to recognise smaller differences.

(2) Results.

Growth responses were determined for four periods which corresponded roughly with spring, summer, autumn and winter; the first and last series were omitted in Trial 2. As there were no significant interactions between treatments, the main effects only will be discussed. Figs. 1-3 show graphically the responses for each of the four growth periods; the results are set out in Tables 3–6.

Table 4.

Growth Increments (sq. cm./plant), December, 1951–February, 1952.

Treatment.	Glasshouse. 5/12/51 to 12/2/52.	Flaxton. 18/12/51 to 19/2/52.	Dagun. 13/12/51 to 13/2/52.	M.E.S. 12/12/51 to 11/2/52.
N1	440	180	201	443
N2	444	210	220	493
N3	375	196	200	458
P0	404	186	201	482
P1	..	..	..	435
P2	419	196	214	476
P3	406	203	207	..
K0	362	175	208	446
K1	..	..	204	427
K2	407	208	209	521
K3	461	202	..	..
Mean	410	195	207	465
Necessary differences for significance 5%	60	N.S.	34	N.S.
Necessary differences for significance 1%	82	N.S.	45	N.S.

Table 5.

GROWTH INCREMENTS (SQ. CM./PLANT), FEBRUARY–MAY, 1952.

Treatment.	Glasshouse. 12/2/52 to 29/4/52.	Flaxton. 19/2/52 to 6/5/52.	Dagun. 13/2/52 to 30/4/52.	M.E.S. 11/2/52 to 1/5/52.
N1	730	563	576	1,185
N2	753	568	626	1,243
N3	669	611	590	1,275
P0	690	546	589	1,302
P1	..	..	..	1,190
P2	732	601	593	1,210
P3	729	597	610	..
K0	633	526	604	1,194
K1	..	..	581	1,172
K2	750	598	607	1,337
K3	768	618	..	..
Mean	717	581	594	1,234
Necessary differences for significance 5%	72	73	68	126
Necessary differences for significance 1%	97	99	92	171

Table 6.

GROWTH INCREMENTS (SQ. CM./PLANT), MAY–SEPTEMBER, 1952.

Treatment.	Glasshouse. 29/4/52 to 9/9/52.	Dagun. 30/4/52 to 15/9/52.	M.E.S. 1/5/52 to 17/9/52.
N1	355	691	860
N2	376	766	891
N3	348	763	941
P0	356	725	869
P1	..	..	936
P2	359	741	886
P3	363	754	..
K0	315	720	907
K1	..	734	904
K2	376	767	881
K3	387	..	..
Mean	360	740	897
Necessary differences for significance 5%	33	59	N.S.
Necessary differences for significance 1%	44	80	N.S.

Rate of growth generally showed a marked increase from the spring on to the autumn period, with a decline during the winter.

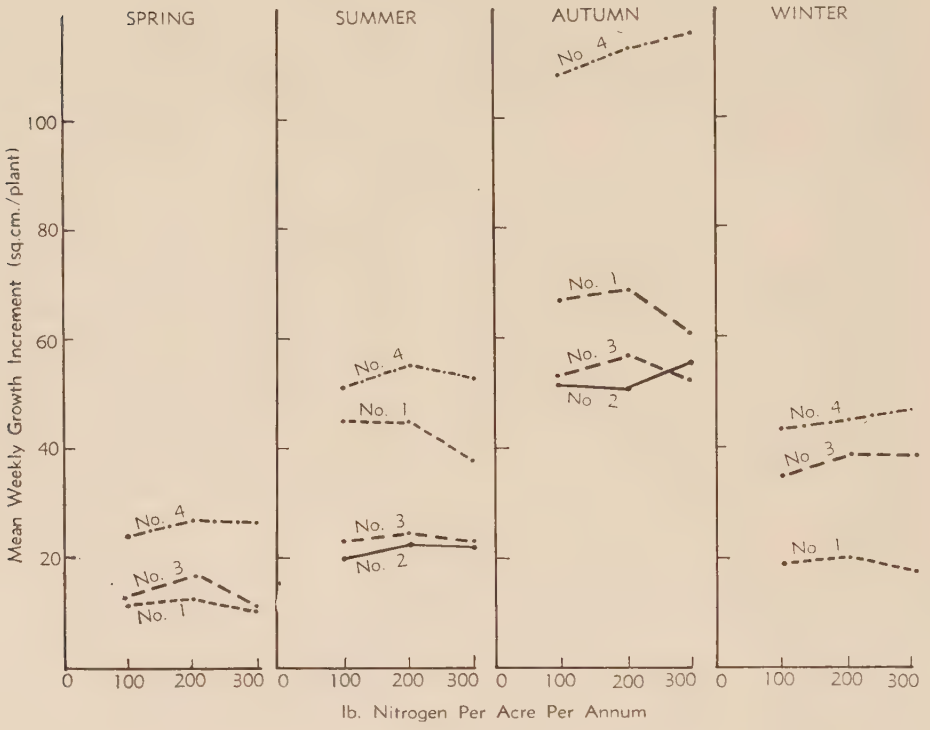

Fig. 1.

Mean Weekly Growth Increments at Three Levels of Nitrogen for Each of Four Growth Periods.

Nitrogen.—The growth curves show a consistent rise in all trials and over all periods with increase in nitrogen from 100 to 200 lb. per acre per annum. In general, the differences were not great and were all below the 5 per cent. level of significance. From 200 to 300 lb. of nitrogen there was in most cases a downward trend, which was most pronounced in Trial 1, in which it reached significance over the summer and autumn period.

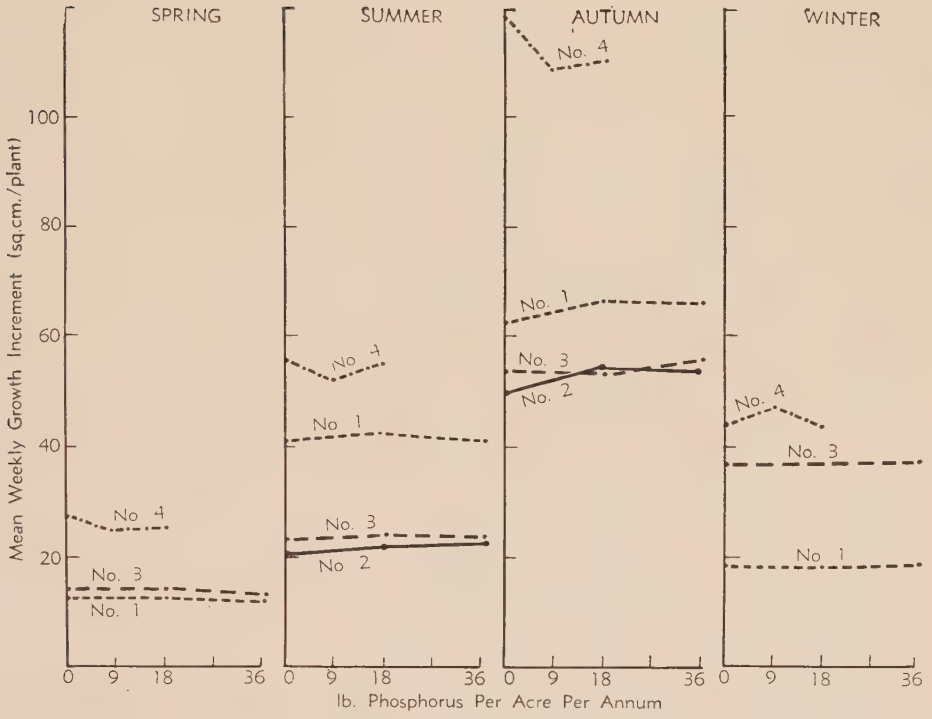

Fig. 2.

Mean Weekly Growth Increments at Four Levels of Phosphorus for Each of Four Growth Periods.

Phosphorus.—With the exception of Trial 4, varying rates of phosphorus had little effect on the growth rate at any period of the year. In this case, a single increment depressed growth over the spring to autumn period, but growth increased with the second increment.

Potassium.—In all trials the rise in growth rate with increase in potassium was fairly consistent over the whole period during which growth measurements were taken. This growth response was significant throughout in Trial 1, but did not reach significance in Trials 2 and 4 until the autumn (that is, just prior to flower initiation).

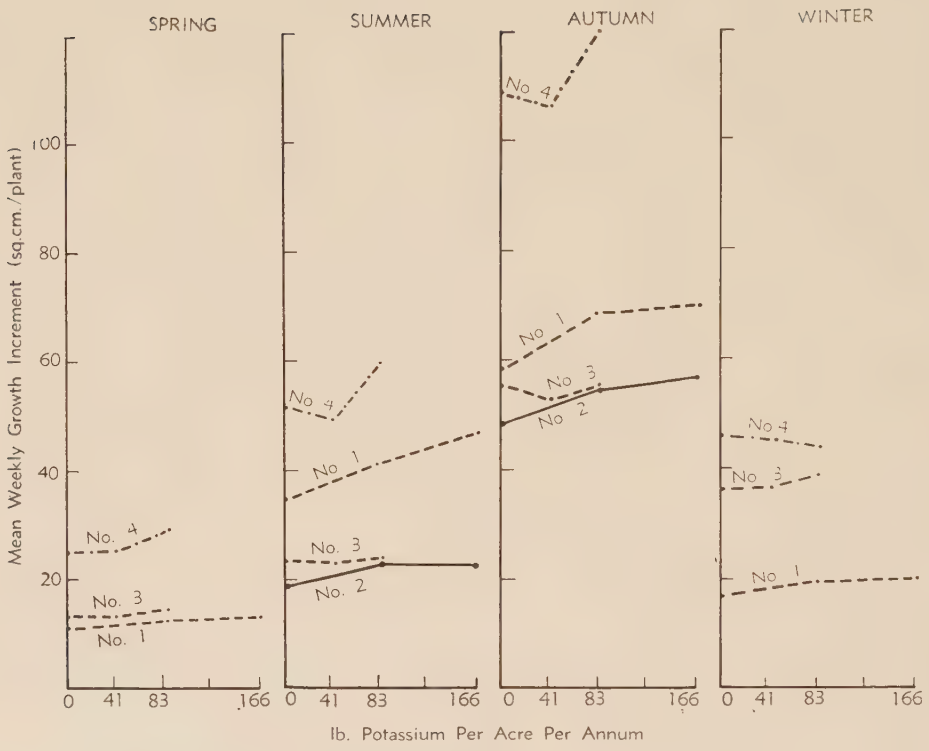

Fig. 3.

Mean Weekly Growth Increments at Four Levels of Potassium for Each of Four Growth Periods.

V. TIME OF FLOWERING.

Flower counts were made in the spring of 1952 to determine whether fertilizer treatments had influenced the time at which the inflorescence appeared. Differences would, of course, be masked by artificial flower induction, and counts were therefore based on the number appearing in advance of the main flowering. This did not apply in Trial 3, where induction treatment was deferred from May to October, and where about 10 per cent. of natural flowering occurred in September.

These effects are set out in Table 7 and shown graphically in Fig. 4. The clearest picture is obtained in Trial 3, since artificial flower induction was not applied until after the natural spring flowering.

Table 7.

FLOWERING COUNTS (MEAN NUMBER OF PLANTS PER PLOT), SPRING, 1952.

Treatment.	Glasshouse. 9/9/52.	Dagun. 1/10/52.	M.E.S. 12/9/52.
N1	31·2	12·7	9·7
N2	31·6	9·3	9·7
N3	32·6	7·7	5·8
P0	33·4	9·4	8·6
P1	..	..	8·2
P2	30·3	10·8	8·4
P3	31·7	9·5	..
K0	37·9	12·2	8·9
K1	..	8·3	8·0
K2	32·9	9·2	8·3
K3	24·6	..	..
Mean	31·8	9·9	8·4
Necessary differences for significance 5%	5·1	2·9	3·9
Necessary differences for significance 1%	6·9	4·0	5·2

On the high-potassium soils (Trials 3 and 4), increase in nitrogen delayed flowering, the effect of the highest level being significant in Trial 4. On a low-potassium soil (Trial 1) a similar effect was produced by each increment of potassium. The overall effect of potassium in delaying flowering was also manifest in Trial 3 on a soil high in potassium.

It would appear that the effect of treatments on flowering time is associated with vegetative growth. The absence of any effect from nitrogen on the low-potassium soils is probably due to the fact that potassium, rather than nitrogen, was the limiting factor in growth.

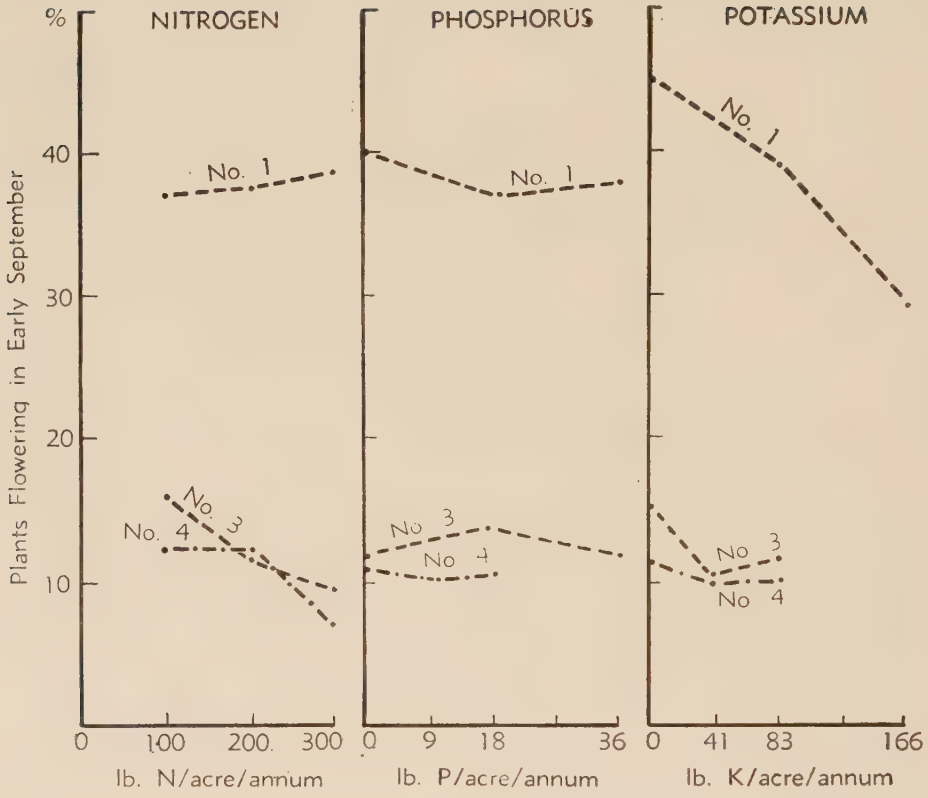

Fig. 4.

Percentages of Plants Flowering in Early September, in Advance of Main Flowering (Trials 1, 3 and 4).

VI. YIELDS.

Yields were based on the summer plant crop, except in Trial 3, where the crop was harvested in the late autumn. Where necessary, and depending on the significance of the regression, yields were adjusted for stand irregularities due to minor disease incidence. The results appear in Tables 8 and 9.

The effect of potassium on yield on the two low-potassium soils (Trials 1 and 2) was similar to the growth response prior to flowering. In the case of Trial 4, the effect of increases in nitrogen was quite apparent in the yields, although the differences in plant growth were not significant.

Table 8.

YIELDS OF FRUIT (TONS/AC. "TOPS OFF") ADJUSTED FOR STAND. PLANT CROP 1953.

Treatment.	No. 1.	No. 2.	No. 3.	No. 4.
N1	18·8	14·0	25·9	23·8
N2	18·8	13·9	25·2	24·8
N3	18·8	14·5	25·4	25·2
P0	18·7	13·9	25·4	24·5
P1	..	..	..	24·7
P2	18·8	14·4	25·1	24·7
P3	18·9	14·1	26·0	..
K0	17·3	13·2	25·6	24·5
K1	..	..	25·5	24·5
K2	19·0	14·4	25·4	24·9
K3	20·0	14·8	..	..
Necessary differences for significance 5%	0·7	0·8	N.S.	0·7
Necessary differences for significance 1%	1·0	1·1	N.S.	0·9

Table 9.

NUMBER OF FRUIT AND YIELDS (TONS/AC. "TOPS OFF")—1ST RATOON CROP, TRIAL NO. 4, SUMMER 1954.

Treatment.	Number of Fruit/80 Plants.				Yields (80 Plants).			
	N1.	N2.	N3.	Mean.	N1.	N2.	N3.	Mean.
P0	87·8	110·7	124·8	107·8	13·7	17·3	19·7	16·9
P1	111·0	110·7	125·8	115·8	18·1	17·9	21·6	19·2
P2	93·2	115·7	136·0	114·9	15·3	19·0	22·2	18·8
K0	95·8	110·8	136·7	114·4	15·1	17·9	22·6	18·6
K1	98·2	108·2	118·7	108·3	16·2	17·6	19·4	17·7
K2	98·0	118·0	131·3	115·8	15·7	18·7	21·6	18·7
Mean ..	97·3	112·4	128·9	112·9	15·7	18·1	21·2	18·3
Necessary differences for significance (main treatments) 5%	..	..	..	10·9	..	..	..	2·1
Necessary differences for significance (main treatments) 1%	..	..	..	14·8	..	..	..	2·9

Trial 4 was carried through to the ratoon crop, which was produced in the succeeding summer (1954), following artificial flower induction. Since the yield of a ratoon crop is influenced by the number of suckers bearing fruit, fruit counts, as well as yields, have been included in Table 4.

The effect of progressive increments of nitrogen on the number of suckers was most pronounced. Yields were directly proportional to the number of fruit—i.e., the number of suckers produced. It is evident, therefore, that the importance of nitrogen to the ratoon crop lies in the promotion of suckering. The yield response to phosphorus, on the other hand, cannot be explained in the same way.

VII. FRUIT QUALITY.

Although yields were the major consideration, fruit quality, especially for canning, is also important. It is difficult to resolve quality in terms of chemical analysis, but tests over a number of years in Queensland have shown that sugar and acid content can be correlated with quality as judged by tasting panels. Fruit low in acid is rather insipid and flavour improves as the acidity increases. Sugar, on the other hand, is very necessary to offset an acid taste and to render the fruit palatable.

Estimations of sugars and acid (Table 10) were made on samples of five fruit per plot from Trials 1, 2 and 4, taking one fruit per plot on each of five successive harvests. Since the sugars in the juice of the pineapple represent about 85 per cent. of the total solids, Brix determined hydrometrically was used as an index of the sugar content. Acids were determined by titration against O·1N NaOH and are given as the citric acid equivalent.

Table 10.

Sugar and Acid Content of Fruit, Expressed as Mean "Brix" (total solids) and Citric Acid Equivalent.

Treatment.	No. 1.		No. 2.		No. 4.	
	Brix.	Acid. %	Brix.	Acid. %	Brix.	Acid. %
N1	14·8	0·54	13·3	0·72	15·2	0·68
N2	14·8	0·52	13·3	0·70	15·2	0·64
N3	14·8	0·50	13·4	0·72	14·8	0·61
P0	14·7	0·50	13·4	0·72	15·0	0·65
P1	..	..	..	..	14·9	0·64
P2	14·8	0·53	13·2	0·70	15·2	0·64
P3	14·8	0·54	13·4	0·72	..	..
K0	14·4	0·44	13·4	0·67	14·9	0·62
K1	..	..	..	..	15·0	0·65
K2	14·9	0·54	13·4	0·73	15·2	0·66
K3	15·0	0·58	13·2	0·74	..	..
Mean	14·8	0·52	13·3	0·71	15·1	0·65
Necessary differences for significance 5%	0·2	0·026	0·2	0·036	0·3	0·047
Necessary differences for significance 1%	0·3	0·036	0·3	0·047	0·4	0·064

Added nitrogen had no effect on sugars in the fruit of pineapples grown on the low-potassium soils, but brought about a progressive decrease on the high-potassium soils, the differences between the highest and lowest levels being significant. It had the opposite effect on acid. Increase in nitrogen progressively decreased the acid content, the differences being significant in two of three trials. The effects of phosphorus were not consistent; in one trial the sugar content was increased and in the other the acid content. The general effect of potassium was to increase both sugars and acid, except for a barely significant decrease in sugars in Trial 2.

VIII. DISCUSSION.

(1) Nitrogen.

Up to the time of flower initiation there was no growth response beyond the level N1, which was equivalent to 100 lb. of nitrogen per acre per annum and only about one-third the amount usually recommended in southern Queensland. In Trial 1 there was actually a suppression of growth at the high level of nitrogen; this was also apparent, though not significant, in Trials 3 and 4. Sideris and Young (1946) reported a similar effect in trials in Hawaii and put forward the view that high NH_4 ion concentrations inhibit intake of potassium.

From flowering to harvesting, a period of about six months, doubling the rate of nitrogen brought about increased growth on the high-potassium soils but not on the low-potassium soils. In the latter soils, it would appear, the major limiting factor was availability of potassium rather than of nitrogen. On one of the high-potassium soils (Trial 4) there were significant yield increases with progressive increments of nitrogen. In the other (Trial 3) the differences were negligible, but it is possible that seasonal influences masked treatment differences. Hence, it may be concluded that nitrogen is required in larger amounts after flowering than in the first year of growth. This is in conformity with the conclusions of Nightingale (1942) that intake of nitrogen is highest during the period of fruit development.

In the ratoon crop (Trial 4) there was a marked response to each increment of nitrogen, both in number of fruit and in total yield. From an examination of the data presented in Table 4 it is obvious that the main effect was a stimulus to sucker production, since yields were directly proportional to the number of fruit (that is, the number of suckers developed). It would also appear that the requirements of the fruit predominate over vegetative needs and that any shortage of nitrogen is reflected in reduced sucker production and subsequent growth.

Fruit quality determinations show that nitrogen tends to decrease both sugars and acid. Excess nitrogen during the period when the fruit is developing is, therefore, likely to have an adverse effect on quality. On the other hand, as indicated above, insufficient nitrogen at this time is liable to reduce suckering and ratoon yields, so that a fairly fine balance is required over this period.

A single series of trials, such as these, cannot take into account seasonal variations, which have an important bearing on nitrogen assimilation. Further work which is in progress to confirm the general conclusions of these trials will no doubt throw more light on this point. In seasons of prolonged cloudy weather, reduction in carbohydrate synthesis may lead to an accumulation of nitrogen in the plant tissues. Hence, seasonal influences will have a bearing on the amount of nitrogen required during this critical period. From the data available it would appear that 100–150 lb. of nitrogen would be required during the six months from flowering to harvesting. Since an important function of nitrogen is the promotion of suckering, the logical procedure would be to supply the bulk of the fertilizer early in the period, when the sucker buds are normally developing.

(2) Phosphorus.

Absence of a response to phosphorus was characteristic of all the trials in the series, except for the inexplicable increase in yield in the ratoon crop of Trial 4. It may be concluded that soils containing 80 p.p.m. or more of available P_2O_5 are sufficiently well supplied to meet the needs of the pineapple plant. Although this was the lowest level in any of the trials, it is not indicative of the status of virgin soils, since Vallance (1938) and Vallance and Wood (1940) reported much lower values for available phosphate in the soils examined in their surveys.

The effect of phosphorus on fruit quality was by no means clear-cut and the results are conflicting. In some cases it appeared to have a tendency to increase acid and possibly sugars, while in others it had the reverse effect.

(3) Potash.

The response to potash was most pronounced on the low-potassium soils. In Trial 1 this was evident through the whole of the growing period, but in Trial 2 it was less marked. In the latter case, it is probable that reduced rate of growth occasioned by lower temperatures was largely responsible for the limited response. Lack of any major responses on the high-potassium soils agrees with Magistad's (1934) conclusions, in relation to Hawaiian pineapple soils, that on soils above the level of 0·50 m-equiv. per 100 g. pineapples do not respond to potassium.

The level K2 was significantly better than K0 in three of the four trials, but was not in all cases significantly inferior to K3. It was evident from growth measurements that potassium is important for vegetative growth and is probably the limiting factor on soils in which replaceable potassium is below at least 0·18 m-equiv. per 100 g.

From the results of these trials it is concluded that relatively large amounts of potassium are required by the pineapple, and that on high-potassium

soils these requirements can largely be met from the soil. In Trial 4 there was a response in the autumn before flowering, though not at other times, which would suggest that the maximum demand occurs at this stage.

IX. CONCLUSIONS.

These trials reveal that, in southern Queensland, the most important nutritional requirement of pineapples is potash, whereas nitrogen is less important than was formerly believed. Current fertilizer practices involve the use of somewhat excessive amounts of nitrogen and, in many cases, inadequate supplies of potash. Queensland pineapple soils vary mainly in their potash content, and this should be taken into account in formulating fertilizing schedules for particular areas.

It is concluded that in the first year—that is, up to the flowering stage—100 lb. of nitrogen and 83 lb. of potassium are required on soils containing over 0·50 m-equiv. per 100 g. of replaceable potassium per 100 g., with the amount of potassium at least doubled where replaceable potassium is below 0·20 m-equiv. per 100 g. A small amount of phosphorus may be required to maintain the phosphorus status of the soil.

From flowering to harvesting, these rates should be doubled to supply the same amount of nutrients in six months as proposed for the first 12 months. The bulk of it should be applied soon after flowering to avoid any possible adverse effect on fruit quality from excess nitrogen.

After the plant crop has been harvested, a high level of nitrogen is required to promote sucker growth for the sake of an early ratoon, and the first application should be at a rate of 75 lb. of nitrogen per acre, possibly without the addition of potash. Subsequent applications may correspond with those for comparable stages in the plant crop.

X. ACKNOWLEDGEMENTS.

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EFFECT OF MOLASSES AND FORMALIN ON THE SOIL STRUCTURE AND PRODUCTION OF FOREST NURSERY SEEDBEDS

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SUMMARY.

Application of molasses to selected forest nursery soils improved soil structure. The improvement was reflected in growth of seedlings and the proportion of plantable stock obtained. The increases in growth were greater than those obtained with partial soil sterilization.

I. INTRODUCTION.

Forest nurseries producing seedlings for reafforestation in Queensland have been worked under monoculture for a number of years. In some nurseries producing *Araucaria cunninghamii* (hoop pine), a gradual decline in the growth of seedlings was noticed, despite the fact that adequate fertilizer was supplied. This suggested the necessity for examining other factors, such as soil structure, which might influence growth.

Nurseries at Yarraman and Benarkin, on the Blackbutt Range in south-eastern Queensland, were selected for investigation. The Yarraman nursery soil is a lateritized clay developed from andesite. The Benarkin nursery soil is a clay presumed to be developed from hardened shales.

Chemical analyses showed no unbalance or great lack of the major nutrients. Analyses of the two nursery soils (0–9 in. depth) are given below.

	Yarraman.	Benarkin.
pH (2 : 5 soil/water suspension)	6·2	5·7
Available P_2O_5 p.p.m. (soluble in N/100 H_2SO_4) ..	256	152
Repl. Ca^{++} (m–equiv. per 100 g.)	6·3	6·3
Repl. Mg^{++} (m–equiv. per 100 g.)	6·4	7·1
Repl. Na^{+} (m–equiv. per 100 g.)	0·41	0·16
Repl. K^{+} (m–equiv. per 100 g.)	0·56	0·31
Total N (%)	0·18	0·18

Experiments carried out at Yarraman by the Sub-Department of Forestry showed that the application of trace elements gave no increase in production, and NPK trials with and without animal manure topdressing at each nursery showed that the greatest growth followed the manure topdressing.

In both nurseries tilth was poor in spite of the presence of sawdust in the soil. This fact, together with the results obtained with manure, led to consideration of the soil structure as a possible cause of low productivity. This idea was supported by preliminary tests which showed that the soil had very poor aggregation. However, because of the many years of monoculture the possibility of a stagnant soil microbiological population could not be ruled out.

With respect to the latter, partial sterilization with formalin followed by re-inoculation with soil from a forest plantation was tried. Treatment with some substance high in easily available carbohydrate so as to give an impetus to the microbiological population was also planned. Since it has been shown by Martin and Waksman (1940, 1941) that the microfloral population in the soil is responsible for a large degree of the aggregation, the second treatment was expected to improve the soil structure. Shortly after the experiment was begun it was shown by Swaby (1949) that fungi in particular exerted a great effect on the aggregation of soil particles. Browning and Milam (1944) showed that sucrose is an excellent material for improving the soil structure. As molasses is a readily available form of sugars and has been applied with good results in sugar-cane soils, it was used in these experiments.

The normal practice for the production of hoop pine seedlings in Queensland nurseries is as follows:—

Plants are grown from seed in high-shade nurseries which provide half shade. Seed is sown by hand in drills 8 in. apart, aiming at eight plants per foot of drill. A cover of $\frac{3}{4}$ in. of hoop pine sawdust is added after sowing, which is done in September. Thinning is done during the first winter following sowing. In the February before lifting—i.e., approximately 18 months after sowing—the seedlings are root-wrenched. Cultivation and weeding are done plot by plot. At the end of the 2-year period, plants are lifted, measured and classified for suitability for planting stock (tubing stock).

II. COMPARISON OF MOLASSES AND FORMALIN.

The following technique was used in comparing the effects of molasses and formalin on the growth of hoop pine seedlings.

Plots were laid out as a randomised block, with five replications. The gross plot size was 5 ft. x 5 ft. with 1-row isolation strips around each of them. Formalin was applied at the rate of 14 gal. of 2 per cent. formaldehyde solution to the appropriate plots, which were then covered with sacking for three days, after which they were uncovered and allowed to stand for 10 days. Inoculating soil was then dug into each plot, which was then raked smooth. Molasses was applied evenly over the surface of the soil at the rate of 14 lb. per plot. The treated plots were allowed to stand for one week, and then lightly watered with 2 gal. of water per plot. After another standing period of one week the soil was dug over to a depth of 9 in. and raked smooth. The normal sowing and tending practices of the nursery followed.

As it became evident after the first trial that the molasses treatment was superior to the formalin treatment, the latter was discontinued and those plots also treated with molasses.

Plant heights were recorded at 3 in. intervals, and the number tubed and the number discarded as unsuitable were also noted. Water-stable aggregates in samples taken from the plots before the seedlings were lifted were determined by the Downes and Leeper (1940) modification of the method of Myer and Rennenkampf.

The results of the first trials are summarised in Table 1, which shows the mean heights and percentages of stock tubed. The aggregate analyses will be discussed later.

Table 1.

SUMMARY OF RESULTS OF FIRST TRIALS.

Treatment.	Mean Height of All Plants. (in.)	Mean Height Tubed Stock. (in.)	Percentage Plants Tubed.
Yarraman.			
Control	5·10	7·07	37·53
Formalin	5·47	7·27	42·32
Molasses	6·28	7·88	54·30
Benarkin.			
Control	7·06	9·67	16·77
Formalin	8·46	10·75	45·30
Molasses	10·42	12·64	61·70

The figures from Yarraman show no significant differences at the 5 per cent. level for the mean height of tubed plants. The mean height of all stock and the percentage of plants tubed show that the molasses treatment produced significant differences at the 5 per cent. level. Better results were obtained at Benarkin, where both the molasses and the formalin treatments are significantly higher than the controls at the 5 per cent. level. Furthermore, the molasses treatments were significantly better at the 1 per cent. level than the control and formalin plots.

III. MOLASSES EXPERIMENTS.

The trials using molasses were repeated for two additional growing seasons, but as mentioned previously the formalin treatments were discontinued and these plots also treated with molasses. For ease in tabulation the molasses plots are designated C treatments and those which were treated with formalin originally are designated B treatments.

Fig. 1 shows the distribution of aggregates for each treatment at Yarraman and Benarkin. The ordinate shows the mass of aggregate minus grit on each sieve.

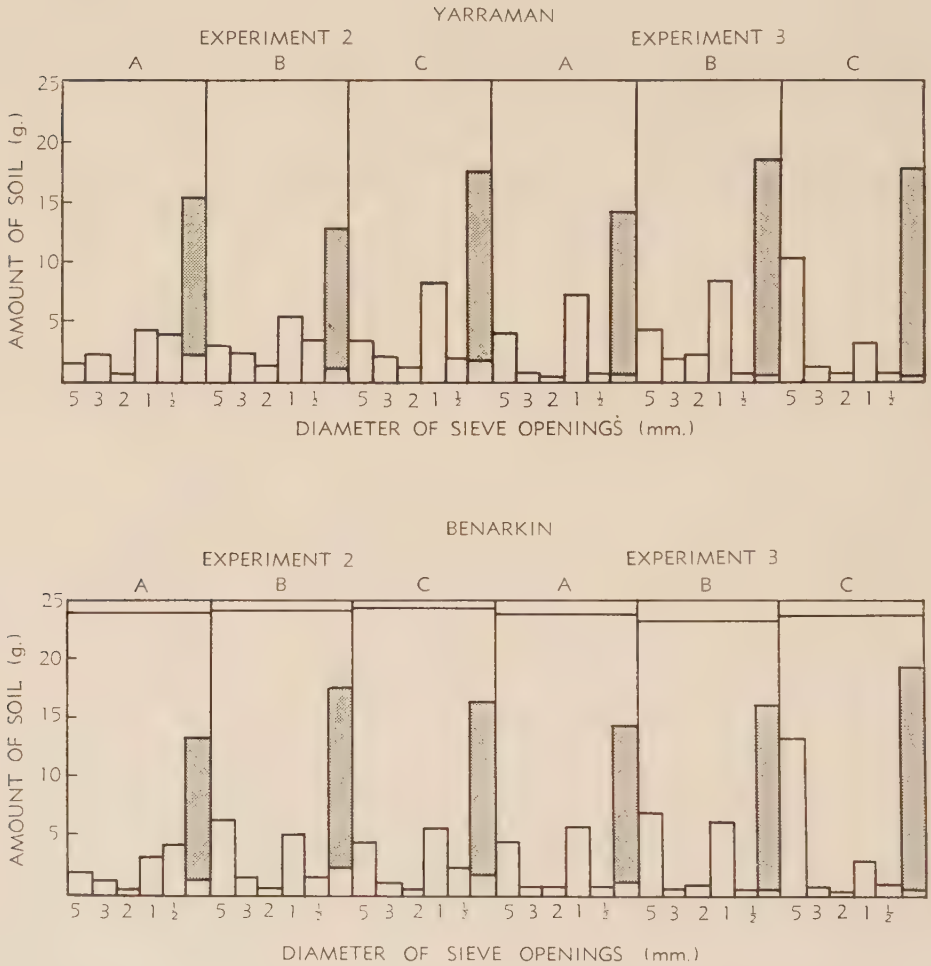

Fig. 1.

Distribution of Aggregates in Experiments 2 and 3. The shaded portion represents the total aggregates retained on all sieves. The portion underneath this represents the quantity retained on a 70 IMM sieve. The horizontal lines at the top of the histograms represent the quantity of oven-dry soil used in the determination.

The change in disaggregation for the different experiments is summarised in Table 2.

Table 2.

PERCENTAGE DISAGGREGATION OF SOILS.

Experiment.	Control.	B Treatment.	C Treatment.
Yarraman.			
1	20·8	20·8*	12·6
2	17·9	13·8	9·7
3	24·0	8·7	7·6
Benarkin.			
1	39·5	39·5*	29·2
2	28·6	27·4	21·1
3	29·2	19·6	11·6

* Formalin treatment.

It will be noted that the effect of molasses treatment is to increase not only the total aggregation but also the aggregate size. This shift from small to large particles is evident in Fig. 1 (Benarkin), which also shows that the shift is in two stages—first, a build-up of 1 mm. size particles, and secondly, a build-up of 5 mm. particles with depletion of the 1 mm. size.

The mean heights of plants in the plots and the percentage of plants selected for planting out (i.e., stock tubed) are given in Tables 3 and 4.

Table 3.

MEAN HEIGHT OF STOCK.

Experiment Number.	Control. (in.)	B Treatment. (in.)	C Treatment. (in.)
Yarraman.			
1	5·1	5·5*	6·3
2	8·3	9·4	9·4
3	8·6	9·4	10·2
Benarkin.			
1	7·1	8·5*	10·4
2	6·4	9·9	9·9
3	6·8	12·1	11·4

* Formalin treatment.

At Yarraman the heights are significantly greater than the control in all except the B treatments in Expts. 1 and 3. The increases in Expt. 3 at Benarkin are not significant; neither is the fall in percentage of stock tubed recorded for the C treatment of Expt. 2 significantly different from the control. The differences in mean height and percentage of stock tubed between the B and C treatments are not significant, but both are significantly higher than the controls.

Table 4.

Percentage of Stock Tubed.

Experiment Number.	Control.	B Treatment.	C Treatment.
Yarraman.			
1	37·5	42·3*	54·3
2	72·8	79·1	70·4
3	70·1	75·1	75·0
Benarkin.			
1	16·8	45·3*	61·7
2	48·2	74·5	87·8
3	54·4	82·6	78·1

* Formalin treatment.

The experiments were complicated somewhat by a severe drought which extended over a period covering the end of Expt. 2 and the beginning of Expt. 3. The effects of the drought were more severe at Yarraman than at Benarkin.

It would appear from Fig. 1 that plant height is related to the amount of 1 mm. aggregates present in the soil but that the quantity of aggregates 5 mm. or greater increasingly exerts an effect contrary to that of the 1 mm. aggregates.

It should be noted that the decrease in disaggregation is the same for Expts. 1 and 2 but that a greater decrease was obtained at Benarkin than at Yarraman.

The differences between the nurseries is due to the different type of clay minerals present in the soils. X-ray diffraction measurements of the clay fractions from the soils were made and powder and aggregate photographs were prepared. The Yarraman clay was found to consist of kaolinite-type mineral with small amounts of montmorillonite and haematite and a trace of quartz. The Benarkin clay was similar but contained approximately 25 per cent. of montmorillonite and approximately 2 per cent. of quartz.

IV. CONCLUSIONS.

Treatment of nursery soils with molasses at the rate of 14 lb. per sq. yd. has been shown to improve the structure of the soils. This improvement in structure is reflected in the increases in height of seedlings grown and in the percentage suitable for planting.

Partial sterilization, although effective in increasing growth, is not as successful a treatment as molasses.

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TECHNICAL NOTE

EFFECT OF 2,4-D AND 2,4,5-T DERIVATIVES ON BLOODWOOD *(EUCALYPTUS DICHROMOPHLOIA* F. MUELL.*)*.

Experiments were conducted on "Brian Pastures" Pasture Research Station, near Gayndah, in the Burnett River region, to test the effectiveness of 2,4-D and 2,4,5-T derivatives in destroying regrowth of bloodwood (*Eucalyptus dichromophloia* F. Muell.). This regrowth had occurred in trees that had been ringbarked but that had regenerated from the trunk below the frill or from lignotubers.

Two methods were tested: (1) applying the herbicide to a frill and to the stumps of severed suckers; and (2) spraying the foliage with the herbicide.

(1) Application to Frill and Stump.

Treatments were applied to separate blocks in early September, 1953 (spring), early December, 1953 (summer) and late April, 1954 (autumn). Each treatment was limited to a single plot containing at least 100 bloodwood trees sufficiently large to be frilled. The trees were up to 15 ft. high and 3-6 in. in diameter. They were completely frill-ringed about 30 in. above ground level; smaller suckers were cut off near ground level.

The mixtures used are shown in Table 1. The concentration in all cases was 1 per cent. acid equivalent of the active constituent.

Table 1.

Details of Treatments.

Treatment Number.	Active Constituent.	Carrier.
1		Distillate
2	2, 4–D sodium salt	Water
3	2, 4–D triethanolamine salt ..	Water
4	2, 4–D triethanolamine salt ..	Distillate
5	2, 4–D ethyl ester	Water
6	2, 4–D ethyl ester	Distillate
7	2, 4–D ethyl ester + 2, 4, 5–T butyl ester	Water
8	2, 4–D ethyl ester + 2, 4, 5–T butyl ester	Distillate
9	2, 4, 5–T butyl ester	Water
10	2, 4, 5–T butyl ester	Distillate
11	2, 4, 5–T butoxy-ethanol ester ..	Distillate

PERCENTAGES OF BLOODWOOD TREES SHOWING REGROWTH FOLLOWING FRILL TREATMENT WITH DISTILLATE AND HORMONE HERBICIDES AT VARIOUS SEASONS.

Treatment.	Spring (3-5/9/53).				Summer (2/12/53).			Autumn (29-30/4/55).	
	No. Treated.	Percentage Showing Regrowth.			No. Treated.	Percentage Showing Regrowth.		No. Treated.	Percentage Showing Regrowth.
		1/12/53.	16/11/54.	16/11/55.		16/11/54.	16/11/55.		16/11/55.
(1) Distillate	119	75	82	90	152	95	96	126	100
(2) 2,4-D sodium salt in water ..	106	41	..	86	113	84	87	110	88
(3) 2,4-D amine in water	146	21	72	83	119	91	91	121	91
(4) 2,4-D amine in distillate ..	134	69	87	90	111	91	92	154	87
(5) 2,4-D ethyl ester in water ..	183	43	73	66	159	97	97	105	90
(6) 2,4-D ethyl ester in distillate ..	122	35	80	66	155	95	94	113	92
(7) 2,4-D/2,4,5-T mixed esters in water	120	23	71	76	136	93	93	153	82
(8) 2,4-D/2,4,5-T mixed esters in distillate	115	15	76	70	130	72	86	162	91
(9) 2,4,5-T butyl ester in water ..	177	32	81	79	159	72	76	134	93
(10) 2,4,5-T butyl ester in distillate ..	186	13	60	90	150	69	77	123	87
(11) 2,4,5-T butoxy ethanol ester in distillate	135	13	67	82	160	55	74	164	91

The mixture was applied to the frill or stump from a knapsack pump, the spray boom being replaced by a copper pipe about 1 ft. long inserted in front of the control tap and curved to facilitate application to the frill. Application immediately followed frilling. An average of 1·6 fl. oz. was applied to each tree.

The percentages of trees that had suckered at various intervals after treatment are shown in Table 2.

In most cases leaf-fall began in less than three months. Regrowth appeared in most cases from the trunk below the frill. In many of the hormone-treated trees these shoots died and were replaced by shoots which developed from the lignotuber.

There was an early response to distillate-based treatments, but overall there was no evidence to suggest that distillate was a more efficient carrier than water. In most cases distillate alone was slightly inferior to the 2,4-D and 2,4,5-T derivatives.

In the December treatments, 2,4,5-T derivatives were more effective than the 2,4-D derivatives; otherwise no differences between the two types were shown.

It is well known that soil type and topography affect the degree of suckering in ringbarked trees. The higher kills in plots 5-8 of the spring treatment are possibly attributable to a greater proportion of trees on the lower slopes in these plots. In plots 7 and 8, suckering on the steep slopes was 90 and 97 per cent. respectively, while on the lower slopes, where the soil was deeper, 50 and 72 per cent. respectively suckered.

The treated area was burnt over accidentally in August 1954 and because of this was again burnt in the spring of 1955 in conformity with district practice. The effect of these burnings could not be measured.

(2) Foliage Spraying.

The same mixtures were tested as foliage sprays on small suckers up to 8 ft. high. The regrowth had commenced three years previously in a stand which had been largely killed by ringbarking 30 years earlier.

The concentration used in each case was 0·2 per cent. acid equivalent, and treatments were given in September 1953, December 1953 and April 1954. The foliage and stems were thoroughly wetted, 1-4 gal. of spray being applied to each plot of two-fifths of an acre according to the density of the stand.

Many plants in each plot were defoliated and numerous aboveground stems were killed, but in all cases some plants showed little, if any, response to treatment. Regrowth commenced in the year following spraying and at the

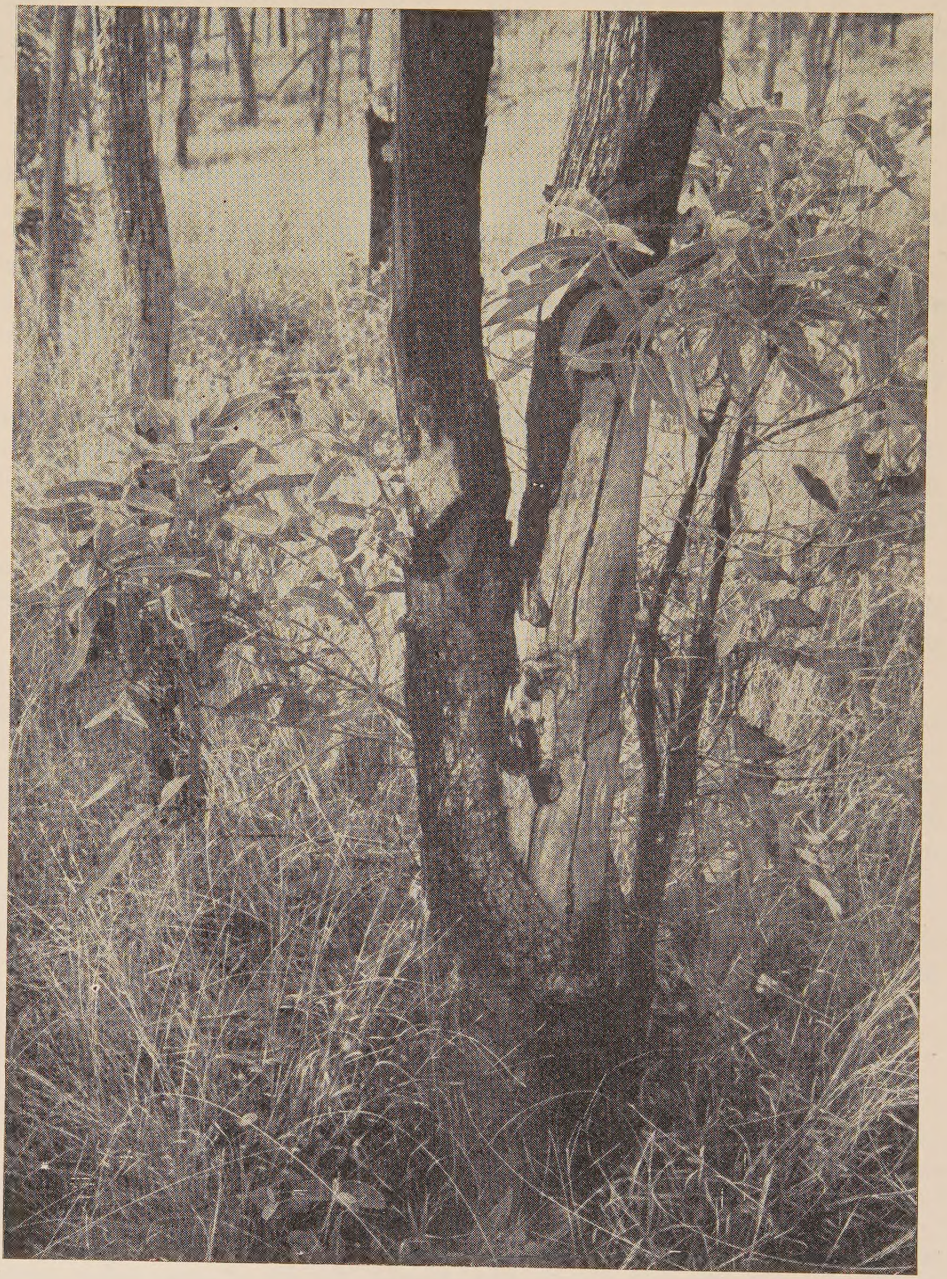

Fig. 1.

Two Regenerations After Treatment Are Shown in this Photograph. The original trunk, ringbarked about 1933, is shown in the centre. The stem on the left appeared following the original ringbarking and was frilled and treated with a hormone preparation in December 1953. A vigorous sucker, on right, has again been produced from the base.

final inspection in November 1955 there was no evidence to suggest that any of the treatments had been even moderately successful. None of the underground parts were killed.

(3) Conclusion.

Hormone-type herbicides, whether applied to the frill or to the foliage, were ineffective in controlling bloodwood regrowth in the concentrations used and under the environmental conditions of the trials.

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